GEOLOGICAL SURVEY OF ENGLAND AND WALES

HONI SOIT QUI MAL Y PENSE

Date Due

Swan Pool, Falmouth.

Lake formed by the natural dam of a beach piled up across the front of the valley. Cliff Section of Falmouth Slate Series in the foreground.

MEMOIRS OF THE GEOLOGICAL SURVEY.

ENGLAND AND WALES.

EXPLANATION OF SHEET 352.

THE

GEOLOGY OF

FALMOUTH AND TRURO

AND OF THE

MINING DISTRICT OF CAMBORNE AND REDRUTH.

BY

J. B. HILL, R.N.,

AND

D. A. MacALISTER, A.R.S.M., F.G.S.

WITH PETROLOGICAL NOTES

BY

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PREFACE.

THE region described in this memoir includes that portion of West Cornwall which is represented by Sheet 352 of the new series one-inch map of England and Wales.

The original geological survey was carried out by De la Beche in connection with the Trigonometrical Survey of Great Britain, then under the superintendence of Colonel Colby, R.E., F.R.S., and in the course of his work De la Beche received valuable assistance from two Ordnance Surveyors, Mr. Henry McLauchlan, F.G.S., and Mr. Henry Still, F.G.S. The results of the original survey were published in 1839 on the old series maps 31 and 33, and in the well-known Report on the Geology of Cornwall, Devon and West Somerset. Additional lodes were inserted on the maps at a later date by Sir W. W. Smyth, and new editions of the maps were published in 1866.

On comparing the new map with the corresponding portions of the older maps it will be noted that important additions have been made. The area formerly represented as Devonian has been separated into Lower Devonian, and into three sub-divisions, based on lithological characters, to which the terms Portscatho, Falmouth and Mylor have been applied. These three sub-divisions, together with the Veryan beds, which were classed as Lower Silurian on the earlier maps in consequence of the discovery of fossils near Gorran Haven by Mr. C. W. Peach, are now regarded as Lower Palæozoic, mainly on account of the evidence supplied by a coarse conglomerate which is well exposed at Flushing on the south side of the Helford River (one-inch map 359). This conglomerate contains rounded fragments and large masses of Portscatho rocks which were veined prior to their inclusion in the conglomerate; and the detailed mapping proves that it comes in contact with various members of the earlier series in such a way as to indicate an important unconformability. No recognisable Devonian fossils have been found in the conglomerate or associated deposits, but the stratigraphical evidence is regarded as sufficient to justify the conclusion that it is of Lower Devonian age.

In the sheet to which this memoir refers the grits of Grampound and Probus are taken as the equivalents of the conglomerate on the Helford River; and the line at their base which runs near to and parallel with the northern margin of the map therefore represents the boundary between the Devonian and pre-Devonian rocks. Amongst the igneous rocks the dominant representative is granite, with which the mineral products of the area are so intimately associated. As this district contains the principal seat of the Cornish tin industry it has

been described in more detail than is usual in a sheet explanation.

The geological survey of the area on the six-inch scale was carried out during the years 1897-1903 by Mr. Hill, with the exception of a narrow tract near the north coast that was mapped by Mr. E. E. L. Dixon. The mineral survey has been done by Mr. MacAlister under the supervision of Mr. Hill; and the survey of the entire area since 1901 has been under the charge of Mr. Clement Reid as District Geologist.

The memoir has been written by Mr. Hill and Mr. MacAlister, while Mr. Dixon has contributed notes of the area which he surveyed. The microscopic examination of the rocks previous to 1901 was done by Mr. Hill, and subsequently by Dr. Flett. The petrographical descriptions of the rocks referred to in Part I. are based on detailed notes supplied to Mr. Hill by Dr. Flett. Mr. MacAlister is responsible for the petrographical and mineralogical information contained in Part II.

The photographs which have been reproduced as plates, with the exception of those representing microscopic features, have been taken by Mr. T. C. Hall, of the Geological Survey.

The MS. six-inch maps of the district, included within the area of the one-inch map, have been deposited in the Library for reference, and copies of them may be obtained.

J. J. H. TEALL,
Director.

Geological Survey Office,
28, Jermyn Street, London,
November 20th, 1906.

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CHAPTER I.

INTRODUCTION.

BY J. B. HILL, R.N.

This memoir describes an area of 216 square miles, of which 186 represent the land surface, while the remainder is occupied by the sea.* Whereas the north coast forms a line of cliffs extending for about 6 miles from Porth Towan to Reskajeage Downs, and broken only by minor indentations, the southern seaboard presents a more sinuous course dominated by the bays of Falmouth and Gerrans. Moreover, the arms of the sea, represented by Falmouth harbour and its confluent creeks, penetrate far into the interior of the county. While the coast line facing the English Channel is less than 12 miles, the inner waters border 80 miles of shore, extending to Trethem, Ruan Lanihorne, Tresilian, Truro, Perranarworthal, Mylor Bridge, and Penryn.

Those estuaries that make so prominent a feature in the eastern belt are the seaward extension of the valleys into which they merge, and it requires little geological discernment to recognise their origin in the submergence of that valley system. The extensive sheet of water forming the Carrick Roads covers an ancient alluvial plain in which the lower reaches of the Fal channelled their course to the sea.

The broader physical features of the area are intimately related to its geology: the districts occupied by the dominant rock types, killas and granite, being strongly contrasted. The granite region, between Budock and Camborne, forms high land culminating in the hill of Carnmenellis, with an altitude of 819 feet, while the summits of Carn Marth and Carn Brea attain heights of 771 feet and 740 feet respectively. The district occupied by the killas is by comparison low lying; it rarely attains an elevation of 500 feet, and by far the greater portion lies below the level of 300 feet.

Notwithstanding the greater elevation and more rugged

* See Sketch Map of the Area, Fig. 1, page 8.

9255. 750—Wt. 5440. 12/06. Wy. & S.

character of the granite, its surface is, on the whole, less deeply trenched than the killas. The latter, in spite of its smooth upland features, has been more extensively channelled by the drainage system, which over large parts of the area has produced a set of deep valleys in such close contiguity that stretches of flat land are comparatively rare. This is particularly the case in the Fal basin, which drains nearly two-thirds of the entire district.

The rivers that water the region are small and of low gradient, affording a strong contrast to the deep and extensive valleys which they traverse. Those which empty on the north coast are short, with a general north-westerly course. The larger of these are the Red River, so called from the mine washings which discolour it, and the stream that joins the sea at Portreath. The straight valley between Parsley and Porth Towan is watered by a very small rivulet, and forms a striking feature from the steepness of its slopes. Its coincidence with a line of fracture has doubtless facilitated its excavation. Dissecting a moorland district covered with heath, its beauty is unfortunately marred by the mining operations that follow its course. The south-western district is mainly drained by the River Cober, which after traversing a large granite tract south of Calvadnack, flows past Helston to the Loe Pool.

The northern district, lying on the outer fringe of the Fal basin, and extending approximately from Tregavethan to Skinner's Bottom, in the parish of St. Agnes, is comparatively flat. The adjacent tract, situated between the granite region and the north coast, although trenched by numerous valleys, has a far more even surface than the corresponding slopes of the eastern area.

Notwithstanding the sharp physical characteristics that distinguish the tracts occupied respectively by granite and killas, that differentiation is mainly confined to those major formations. Neither the multitude of elvan dykes, the greenstones, nor the mica traps are expressed on the topography, and the same may be said as regards the smaller granite intrusions that flank the larger bosses. Moreover, the killas itself, notwithstanding its lithological variations from arenaceous to argillaceous, exhibits a general absence both of rock protrusion and features. The inequalities of its surface appear to have resulted almost entirely from river erosion, so that if the valleys were refilled the outline so restored would constitute an undulating platform. The latter would slope seaward to either coast from more elevated land situated on the northern margin of the map between Trevissome and Mount Hawke, where about three square miles range from 400 to 500 feet above sea level. Thus almost the whole of this plain, built up chiefly of killas, and extending across the county from the English to the Bristol Channel, lies below a level of 400 feet, while the greater part does not attain a height of 300 feet. Moreover, the line of cliffs, sometimes reaching 250 feet on the north coast and 100 feet on the southern seafront, tends still further to bring out the even surface of the platform, which,

devoid of craggy features, is suggestive of a plain of marine denudation that was upheaved in comparatively late geological times. Although the gravels of Polcrebo represent the sole evidence of deposit between the Palæozoic period and the era of the Pleistocene raised beaches, the adjoining districts on the north, west and south contain the relics of Tertiary sediments that in all probability were formerly spread over the less elevated portion of this sheet. The Tertiary beds of St. Agnes are indeed only a mile distant, where they reach a height of 375 feet. The gravel deposit of Crousa Downs, in the map to the south, occurs at 360 feet above sea level, while the Pliocene beds of St. Erth, on the map to the west, attain an elevation of 150 feet. From these considerations it appears probable that the killas platform was entirely buried beneath the Pliocene seas, from which the granite domes of Carnmenellis, Carn Marth, and Carn Brea rose out as islands.

The scenery of the area, therefore, has been mainly sculptured since the early part of the Pliocene period, although the solid structure from which it has been evolved is of Palæozoic age: the post-Tertiary accumulations being comparatively meagre, while Tertiary deposits are marked by the solitary instance at Polcrebo.

Although the greater part of the rock platform consists of killas, the less elevated granite tracts likewise cover a considerable area. The killas is of "Silurian"* age, with the exception of a narrow tract across the northern edge of the map, forming the most elevated killas area, that represents the basal Devonian, and marks an important unconformity between the older and newer Palæozoic formations of Cornwall.

In the original Geological Survey map of Cornwall, De la Beche separated the killas into two divisions, viz., a grauwacke group and a carbonaceous series. Thus the former, lying below the Culm-measures, was undifferentiated for the reason, as explained in his Report,† that the progress of geology at that time only warranted the broadest generalisations. He then expressed the opinion that the terms Cambrian and Silurian should be restricted to the areas that gave rise to the prolonged researches of Sedgwick and Murchison, and deprecated the extension of that nomenclature to districts that had not received the same detailed investigations. In a later and undated issue of the map the grauwacke group is divided into Devonian and Silurian, presumably by the authority of Murchison. The Devonian colour was not only applied to the fossiliferous strata of East and Mid-Cornwall but likewise to the unfossiliferous strata in the west. The Silurian colour, on the other hand, was restricted to a belt that had yielded organic remains. Murchison, however, was of opinion that the older division extended far beyond those limits into the barren strata coloured as Devonian, and it is evident that the latter tint was adopted as a matter of convenience, in the absence of sufficient data to go upon, as no re-examination of the area

* The term Silurian is here used in the sense adopted by Murchison for the Upper Silurian and Lower Silurian (Ordovician).

† "Report on the Geology of Cornwall, Devon and West Somerset," pp. 38 to 41.

seems to have been undertaken.* The known Silurian region was confined to the coastal belt between Chapel Point and Gerrans Bay, a boundary connecting those localities admitting of the ready isolation of that region from the rest of the country. That such a broad generalisation, however, was only regarded as provisional, may be inferred from the absence of a line on the map between the two divisions.

It will be seen, therefore, that the sub-division of the killas as the result of the recent survey in no sense invalidates the map published by De la Beche, who made no attempt to distinguish between Silurian and Devonian, while as regards the amended issue of the map, the boundary between those systems, evidently intended as provisional, and for which no line was attempted, has been replaced by a line that more accurately demarcates their limits.

In the present state of our knowledge with regard to South-West Cornwall it is clear that the main portion of the rocks originally grouped as "Silurian" is of Lower Silurian or Ordovician age; that some bands of Silurian proper, or Upper Silurian, also occur in places; and that some of the killas may possibly be of older date. Therefore, in referring generally to these rocks, the term Lower Palæozoic will be most appropriate.

Prior to the accumulation of the Devonian sediments, these older strata were consolidated, cleaved, and brecciated, and to some extent upheaved.

At the close of the Carboniferous period these Lower Palæozoic rocks were again brought within the influence of crustal disturbance, by which they were folded, fractured, and cleaved in common with the overlying Devonian. As a result of this deformation, almost all trace of organic life appears to have been obliterated from the killas represented in this sheet. With the exception of an occasional crinoid fragment, the sole relics of life that have survived are radiolaria, the preservation of their casts being in no small measure due to the minuteness of these tiny creatures, as well as to the siliceous nature of their skeletons. Although it is to be hoped that definite species of fossils may yet be obtained in our district from these strata, they have yielded nothing to warrant their precise correlation with the well-known Lower Palæozoic sub-divisions. The small Devonian tract along the northern edge of the sheet has hitherto proved unfossiliferous, but its northerly extension in the adjoining map has yielded Lower Devonian fossils.

The post-Carboniferous crustal movements ultimately found relief in the intrusions of granite that enter so largely into the geology of this area. These igneous irruptions have metamorphosed the adjacent killas, so that in addition to mechanical alteration induced by the earth movements, the killas lying within that metamorphic aureole has been subjected to chemical change, resulting in the production of new minerals. These granites are also flanked by intrusive greenstones that share both in the pre-

* See references, p. 19.

granitic earth-movements and in the subsequent contact metamorphism. After the solidification of the granite the igneous disturbances were still further expressed by an extensive fissuring of the area. While some of these fractures were occupied by elvan intrusions, others became the repositories of the mineral ores.

At the close of the Carboniferous period the rockbuilding of the area had apparently been completed, with the doubtful exception of the small assemblage of mica traps that are possibly of Permian age. The geological history is not again taken up until the emergence of the plain of marine denudation from beneath the Pliocene sea. The uprise of that sea floor, with its islands of granite, produced a land surface that has since been deeply furrowed by erosion. The sculpture of the district has not, however, been confined to denudation, but oscillatory movements, involving fluctuations in the mutual boundary of land and sea, have been potent factors in determining the character of the scenery. Thus while erosion has been in constant operation on the body of the land, its coastal fringe has been subjected to oscillations that have checked the ravages of the waves. The preservation of shreds of the Pleistocene beach at only a few feet above high-water mark shows that the modern cliff line has undergone but slight modification since pre-glacial times. Similar evidence demonstrates that the existence of the Carrick Roads as an arm of the sea is of like antiquity, and that its divergent estuaries penetrated the adjacent valley system, at least as far as the tidal waters do to-day. After the close of the glacial period the land stood fully 50 feet higher, so that the sea must have retreated from the river valleys of the Fal. Finally, the land surface so upheaved once more began to sink, and the valley floors from which the sea had been excluded were again buried beneath the waves. Moreover, the ancient woodlands that flourished in those vales are still partially preserved beneath the shingle, as the existence of the submarine forests fronting the valleys so clearly testifies. That submergence has resulted in the general coincidence of the modern shore line with that of the Pleistocene sea. (Plate II.)

The geological history, therefore, since the evolution of the Pliocene valley system, records two submergences of approximately equal magnitude, divided by a period of elevation. The latter was characterised by the rigorous climatic conditions of the glacial age, during which glaciers issuing from the ice-field of South Wales reached the Bristol Channel. Although this district lay beyond the southerly limits of the *mêr de glace* beneath which the greater part of Britain was buried, and therefore escaped the devastating effects of glacial action, to which immunity we owe the preservation of the china clay deposits, that epoch nevertheless set its mark on the topography. In winter, while the higher ground was covered by snow, the soil cap on the barren slopes was deeply frozen, so that the summer thaws, acting on a surface unchecked by vegetation, induced an extensive sweeping of the subsoil to the lower lands, which creeping seaward, ultimately found repose on the elevated platform

of the Pleistocene beach. The post-glacial subsidence brought this "head" within the destructive action of the breakers, but sufficient yet remains on the more sheltered portions of the sea-front to modify the coastal scenery. Concomitant with this great surface creep over the body of the land, the valleys were swept out and deepened by the torrential conditions that then prevailed, under which only the heaviest materials could find a resting-place along their beds. It is to the violence of those denuding agencies that we owe the formation of the stream tin deposits, that not only were the means of bringing Cornwall into contact with the ancient civilisations of the East, but afforded its inhabitants a thriving industry for many centuries.

The history of the topography would be incomplete without a brief reference to the later physical changes that not only bring the cycle of evolution down to historic times, but carry it forward to the present day, so that by studying the geographical modifications that are yet taking place within our own observation we may anticipate the changes that the future has in store.

That the present denudation of the land is undoubtedly slower than of old may be gathered from the small volume and sluggish currents of the streams that now water valleys of considerable magnitude. This inference is confirmed by the scanty alluvial deposits that have accumulated on the valley floors since the glacial period. That denudation is nevertheless effecting its influence on the configuration of the area is vividly brought home by the rapid silting up of some of the estuaries. This is well exemplified by the mud flats of the River Fal, which below Ardevora are creeping rapidly seaward. Above Lamorran and Ruan Lanihorne the alluvial terrace has been formed since the sixteenth century, while the upper extension of that flat as far as Tregoney has been recovered from the sea since the time of the Roman occupation, when that place served as a port accessible to shipping. The seaward growth of the valleys and the shallowing of the tidal estuaries are further discussed in the subsequent chapters. While denudation, therefore, in spite of lowering the surface of the land, is gradually extending its frontiers within the sheltered estuaries, the sea front is brought under the ceaseless action of the breakers, and the cliffs are undergoing a slow but constant degradation. During the last quarter of a century the footpaths skirting Gerrans Bay have been gradually shifted back, consequent on the landslips that accompany the undermining of the cliff foot, while the picturesque caverns along the seaboard have undergone extensive alteration. It is evident, therefore, that the effects of coastal erosion alone, if unchecked by elevatory movements of the land, will gradually evolve a submarine plain from which the granite domes will emerge as islets, and that the general conditions of the ancient Pliocene sea will be reproduced.*

The mineral area is practically restricted to the western

* For a fuller account of the evolution of the valley system, its relation to the estuaries, and the history of the deposits that line their respective floors, the reader is referred to the sequel. (Chapters X. and XI.)

half of the sheet. A line drawn from Metheruny on the extreme south, to Baldhu, and from thence in a north-west direction to the coast, defines the eastern limits of the principal metalliferous zones. Between that line and the meridian of Truro the mineral ores are sparsely distributed, while the area farther to the east has proved unproductive. The belt of country enclosing Camborne and Redruth has ever been and still remains the principal seat of the Cornish mining industry. Mining operations within this sheet are practically confined to that limited tract, beyond which, where not entirely discontinued they are conducted on a restricted scale.

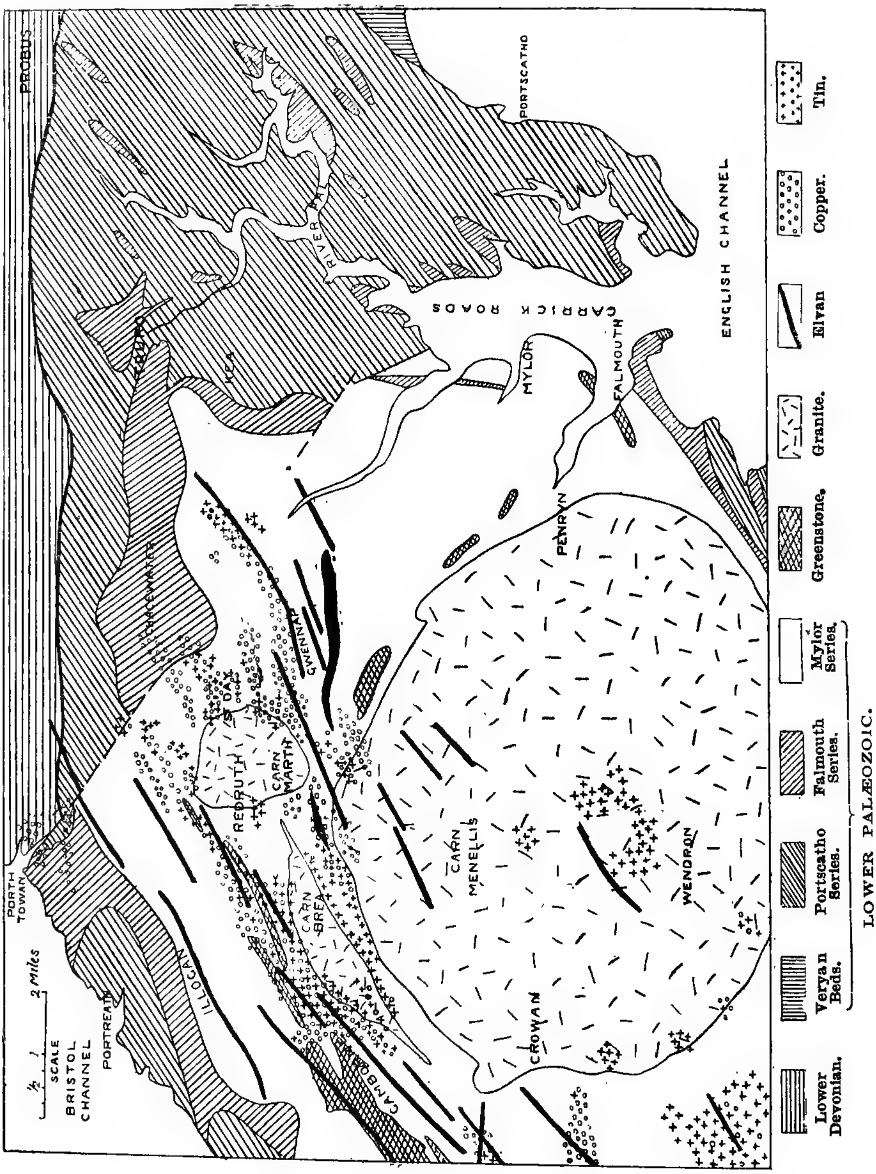
A glance at the map reveals the close connection between the metalliferous deposits and the granite. The eastern half of the Carnmenellis mass is comparatively free from mineral veining, and this has materially contributed to the commercial value of the granite which has been so largely wrought in that area. Proceeding westward, however, from the parish of Wendron, mineral veins make their appearance. They reach their greatest extent on the north-westerly margin of the granite, while the tract enclosing the two adjacent masses of Carn Brea and Carn Marth constitutes the heart of the mineral area. (Fig. 1.)

The granites are dome-shaped masses and slope beneath the killas for considerable distances from their surface outcrops. The sediments which flank them have been considerably altered by contact action, producing an encircling metamorphic belt the variable width of which is controlled by the angle at which the granite slopes below the surface. This dip is by no means constant, as mining operations show. The unevenness of the granite surface is exemplified by the Carn Brea mass, which has been shown to be connected with the granite of Carnmenellis beneath the basin of killas that divides them.

The aureole of metamorphism flanking the eastern portion of the Carnmenellis granite seldom exceeds a width of a thousand yards, and is in some places considerably less; that area, both as regards the granite and the metamorphic belt, being comparatively non-metalliferous. On the western side, however, the granite plunges less steeply beneath the surface, and the metamorphic aureole is therefore considerably larger. Between the Cober Valley and Crowan its average breadth is about a mile. From the granites of Carn Brea and Carn Marth, in the direction of the north coast, the killas is metamorphosed for distances of two and even three miles, and it may be confidently inferred that this tract is underlain by granite, in some places within a thousand feet of the surface.

The mineral district of Gwennap, St. Day, and Baldhu occupies the Carn Marth aureole on its western side, while its eastern extension is characterised by a plexus of elvan dykes amongst killas which exhibits a feeble degree of metamorphism, as indicated by the development of an incipient type of spotting. The south-western region of Crowan and Wendron contains mineral lodes not only within the Carnmenellis granite, but in the intervening killas area, separating that mass from the granite of Godolphin.

FIG. 1.—*Sketch Map to Illustrate the Geology of the Falmouth Sheet* (352).



In the remaining district west of Truro and the Carrick Roads the lodes are scattered and of comparative unimportance, and mainly confined to ores of lead and zinc. These minerals, however, have no necessary connection with the granite intrusions, as is the case with tin and copper.

It will be seen, therefore, that not only are the tin and copper lodes restricted to the granite regions and the adjacent killas, but that they principally occur in areas where the granite plunges beneath the sediments at a low angle. The ores of tin and copper have furnished the staple mining industry of the district, the metals with which they are associated being seldom sufficiently abundant to be profitably wrought on their own account. Beyond the tin and copper districts, however, lead ores have proved remunerative, but mainly from their argentiferous products, which in some cases have yielded a high percentage of silver.

The concentration of the mineral ores is intimately related to the rock structure of the district. Besides the restriction of the tin and copper ores to the granite, and the killas that is immediately contiguous, their concentration in the form of lodes has been controlled by the system of rock fracture pertaining to the area, the fissures having afforded the necessary channels by which the metallic vapours and solutions have travelled, while their walls have received the metallic and other contents with which those currents have parted. The tin and copper lodes are probably of late Carboniferous age, and followed closely on that phase of volcanic activity which is represented by the cooling of the granite and the disruptions that accompanied it. The absence of those metals in the cross-courses, that represent lines of fissure transverse to the Carboniferous fractures, shows that their deposit had ceased prior to that later phase of disruption which there is reason to suppose was brought about by the volcanic disturbances of early Tertiary times.* The deposition of other ores, however, and notably those of lead, silver, and zinc, have continued into Tertiary times, and are of common occurrence in the cross courses.

The decadence of the mining industry has proved a serious obstacle to the survey of the mineral area, and the limited number of workings available for inspection has precluded such systematic investigation as would warrant the formulating of general laws governing the vein deposits of the region. The active mines have been explored by Mr. MacAlister, but much of the mining material in the subsequent chapters has necessarily been derived from previous publications, the authority for which has been acknowledged. The most laborious work in connection with the mineral survey has consisted in the reduction of the lodes to a uniform scale from the mine plans. Most of the latter are laid down to their individual magnetic meridians, so that a plan in use for many years contains errors due to compass variation. Each mine has its own datum line, the depths being taken either from the brace of its shaft, or its adit, which may occur at any depth down to the 40-fathom level. The depths, more-

* J. B Hill. *Trans. Roy. Geol. Soc. Corn.*, 1901, vol. xii., p. 599.

over, instead of being vertical, are calculated along the underlie of the lode. The scales adopted in the different mines likewise vary from 4 to 20 fathoms to the inch. While the accuracy of the plans of the mines now working leaves nothing to be desired, those relating to many of the abandoned undertakings abound with errors, and in some cases Mr. MacAlister has been unable to obtain any plans.

On the map the tops of the lodes only have been delineated. On the 6-inch mining maps, however, the most important of which will be published, they are also represented by underground parallels, the highest of which is at sea level, while the remainder are drawn at uniform vertical distances from Ordnance datum, so that their subterranean behaviour may be grasped. The lodes of the principal mineral areas have also been drawn in MS. on 25-nch maps, which may be consulted in the Geological Survey Office in London.

With the revival of the Cornish mining industry that is now taking place, the mapping of these underground fissures on a uniform scale, with the depths to which they have been proved and by which they can be systematically traced, should materially facilitate future exploration for their mineral wealth. Even if the present attempts to resuscitate the industry should prove abortive, this mineral region is in no sense an abandoned mining field in which the products have been exhausted. The history of Cornish mining presents times of prosperity succeeded by periods of depression, and whatever may be the outcome in the immediate future the time will inevitably recur when economic conditions will again justify a vigorous prosecution of the industry.

The scenery of the area is strongly contrasted. While the eastern region constitutes one of the most picturesque districts of Southern England, the central and western areas are comparatively tame. Moreover, the despoiling of large tracts in the west by the many centuries of mining still further accentuates these scenic contrasts. Although the former region, extending to the west as far as Penryn, Perranwell, Killiow, and the valley of the Kenwyn, is highly fertile and entirely under cultivation, and broken by deep valleys along the slopes of which woodland tracts are profusely scattered, the dominant feature in the topography is the submerged valley system, which has given access to the sea along the numerous creeks that penetrate the very heart of the district. The navigable waters of the Fal, winding amid verdant slopes that are sometimes clothed with woodland to the water's brink, constitute a waterway the beauty of which is probably unrivalled in England, while its seaward extension has furnished one of the finest harbours of the world.

Whereas beyond Truro and Falmouth the passage westward into tamer scenery is somewhat gradual, the central belt between Truro and Perranwell is suddenly replaced by a dreary tract, the bleakness of which is accentuated by the most abrupt transition. The oncoming of these conditions is due to the presence of the mineral belt extending from Carnon and Baldhu

to St. Day. Although mining operations in the district have ceased, a considerable part of the ground is out of cultivation, and large tracts mark the site of the old spoil heaps which in the district east of St. Day cover a considerable area. This wide expanse, that may be described as a vast wreckage, is dotted by engine houses and mine stacks in various stages of decay that still further add to the unsightliness of the landscape. The borders of this tract have in some cases been reclaimed from the dreary features of an abandoned mining district by the planting of timber, as at Gwennap and Scorrier. The *Pinus insignis* and other conifers easily thrive on such burrows as do not carry a high percentage of arsenic, and it cannot be doubted that much of the landscape could be restored by judicious planting from the waste to which mining operations have reduced it. The extensive nature of the subterranean excavations is vividly brought home in this district by the steam which issues from some of the shafts that reach the heated waters below.

The extension of this mineral belt from Redruth to Camborne is accompanied by a softening of the scenery. That tract forms a slope extending to the north coast. Not only does the landscape improve from its blending with the sea, but it is backed by the rugged and picturesque peak of Carn Brea, which commands a magnificent prospect extending right across the county from sea to sea. Viewed from that summit the vast array of stacks forms an imposing scene, and in spite of the large number that represent abandoned operations, the principal seat of Cornish mining still lies beneath the shadow of Carn Brea, and contains the deepest tin mine in the world. (Plate III.) The decadence of mining after the abandonment of operations in the outlying mineral districts, has driven the industry back to its last hold, and on the ability of this mining centre to emerge successfully from the recent period of depression lies the hope of the regeneration of Cornish mining in the immediate future.

The south-western district is dominated by the Carnmenellis granite that forms an elevated dome without conspicuous features. Except on its flanks the population is sparse, and the area is largely made up of moorland out of cultivation and given over to gorse and heath. The western portion, especially in the parish of Wendron, marks the site of an abandoned tin industry. Many valleys and basins, in which the stream-tin has been worked, are choked from side to side with disordered ground. Large tracts of such waste land occur in the upper parts of the Cober Valley, and notably at Porkellis Moor, while another basin similarly desolated lies between Calvadnack and Menerdue. The eastern portion of the granite region is more thickly populated, and forms the seat of the important granite industry, the headquarters of which is at Penryn. The rudely stratiform weathering of the granite frequently results in the production of picturesque tors, of which Carn Brea forms a conspicuous example, while Crowan Beacon and other summits display the same type of scenery on a less imposing scale.

The scenic contrasts of the tracts bordering the northern

coast and those fronting the English Channel are most marked. Although somewhat similar in their geological characters, the greater elevation and bleaker aspect of the former has produced large expanses of moorland represented by Reskajeage Downs, Carvannel Downs, and Nancekuke Common. The southern slopes, on the other hand, are in a high state of cultivation, diversified by luxuriant hedgerows and frequent clumps of woodland, while the more sheltered hollows are capable of sustaining a sub-tropical vegetation that has induced the garden culture of palms and other exotics.

The inland area is entirely devoid of lakes, with the exception of those artificially formed near Antron and Crowan by damming the streams, for the water supply of Falmouth, Penryn, and Camborne. At Swanpool, however, a storm beach that has been piled up across the mouth of the valley has succeeded in ponding back a freshwater lake. (Plate I.)

A conspicuous feature in the upland areas is the presence of shallow basins, which are especially common at the heads of the valleys. They are largely composed of clay, and the want of fall rendering drainage difficult, their bottoms are frequently lined with marshes. Being on this account unsuitable for cultivation, these moors are given over to scrub and gorse and afford coverts for game, just as many of the rocky slopes in the granite district consist of moorland stretches, clothed with gorse and bracken, the recesses of which form the congenial haunts of the fox.

The larger towns in the area comprise Falmouth, Truro, Redruth, and Camborne. While the latter is the principal mining centre, Redruth serves, in addition, as a market town for the western region, while Truro and Falmouth fulfil a similar object for the eastern districts. Although the shipping trade of Falmouth has suffered a serious decline since the advent of steam, it still yields employment to a considerable section of the population, both ashore and afloat. Of late years the town has advanced rapidly in favour as a health resort, the mildness of the climate and the beauty of its surroundings being responsible for a large influx of winter visitors.

PART I.

GEOLOGY.

BY

J. B. HILL, R.N.

CHAPTER II.

FORMATIONS AND THEIR GENERAL DISTRIBUTION.

As a glance at the map will show, the south-western portion of the area is occupied mainly by GRANITE. The principal mass, the most elevated portion of which forms the hill of Carnmenellis, is rudely circular in shape, and, with the exception of a small portion of its southern edge, falls entirely within the district. It extends from Budock on the east to the neighbourhood of Crowan on the west, while its northern limits occur at Buller Downs, about a mile to the south of Redruth. The lenticular mass of Carn Brea, with a linear extent exceeding four miles, is an inlier of the Carnmenellis granite, and separated from it by a narrow basin of slate. The granite situated between Redruth and St. Day, the highest point of which forms the hill of Carn Marth, is boss-like in form, and its southern edge is separated from the Carnmenellis granite in the neighbourhood of Lanner by less than half a mile.

Besides the masses of Carn Brea and Carn Marth, the Carnmenellis granite is fringed by smaller granite intrusions between Crowan and the valley of the Cober, numerous sections of which are exposed in the cuttings of the railway between Praze and Helston. On the east two small bosses of granite are seen at Budock, and fine-grained granite is also exposed close to the main mass in the railway cutting near Treluswell.

The GREENSTONES are mainly confined to the neighbourhood of the granite aureole. They are most extensively developed between Camborne and Coswinsawsin, and continue from the former locality as far as Redruth, in which direction, however, they are seldom visible at the surface. They occur also in the park of Pendarves House, but do not protrude there from beneath the soil. A fairly extensive mass of greenstone lies to the south of Gwennap, between Treviskey and Pengreep, and it follows the same line in close contiguity to the granite between Ponsanooth and Lower Treluswell. Rocks of this group occur on both sides of Penryn Creek, between Flushing and Falmouth, and a few exposures of small size are seen at Carclew and Restronguet Creek. On the southern fringe of the granite, extending from Budock and Praze to the southern limit of the sheet, the sole greenstone that has been recognised is situated in the valley of the Cober, near Tregannock Mill, and is a member of an important group lying further south in the vicinity of Helston.

ELVAN DYKES are abundantly distributed along a belt of country about three miles in breadth, extending from Truro to the neighbourhood of Camborne, and including the districts of Chacewater, Gwennap, and Redruth. Beyond that belt they are sparsely met with west of the Carrick Roads, and the continuation of that waterway to Truro and the valley of the Kenwyn. In the remaining area to the east of that line they have not been detected.

The MICA TRAPS are confined to a narrow belt of country between Pendennis Point and Malpas, and to a small isolated tract at Shortland End, lying to the north-west of Truro.

Of the "Killas" or Slate divisions the MYLOR SERIES is largely developed in the south-west. It completely encloses the granite masses and the greenstones, and contains also the bulk of the elvan dykes. It is bounded approximately by a line drawn from Falmouth along the Carrick Roads to Restronguet Creek, whence it extends north-west to Carrine Common, Baldhu, and the vicinity of Mawla. Thence the line sweeps to the south-west by Illogan, Tehidy House, and Kehellan, at the western margin of the map.

The FALMOUTH SERIES is not so extensive as the Mylor and Portscatho series which it divides. It likewise occurs as lenticles within those groups. To the north-west it occupies a narrow strip which reaches the sea at Reskajeage Downs. A broad tract extends from Chacewater to Truro, from which it branches irregularly to the north-east, south-east, and south. Numerous lenticles occur amongst the Portscatho slates in the basin of the Fal, where they are well developed between Ruan Lanihorne and Philleigh, and from Coombe to Feock. Similar strips appear on the eastern side of the Carrick Roads between Turnaware Point and St. Just, while further to the south these slates are developed at St. Mawes. A wide belt of this series extends from Falmouth to Pennance, and a smaller band occurs at Maen Porth. This group, situated in the neighbourhood of Falmouth, presents favourable facilities for its study from the excellent coast sections in that vicinity.

The PORTSCATHO SERIES occupies almost the entire area east of the Carrick Roads and Truro. It extends west of the Fal from Feock to Killiow and Truro. From Truro to Porth Towan it is developed in a continuous belt. In the neighbourhood of Portreath a large mass borders the north coast with a sea frontage of nearly three miles. The extensive coast sections, both along the seaboard and those afforded by the estuaries that have penetrated far into the interior of the area, present unrivalled opportunities for the investigation of this series.

The VERYAN SERIES occupies a small tract on the north of Gerrans Bay to the east of Pendower.

The GRAMPOUND AND PROBUS SERIES forms a narrow strip across the northern edge of the map between Probus and Porth Towan.

The SUPERFICIAL DEPOSITS are of relative unimportance. The gravels referred to the Pliocene occupy an insignificant tract in the vicinity of Polcrebo. Although the extensive valley system is a marked feature in the district, its floors are seldom

lined with alluvial deposits at all commensurate with the magnitude of the valleys. Moreover, the margins of the alluvia are generally far less defined than is usual with this class of deposit, and it has been found desirable in some instances to include within the alluvial boundary tracts which in other districts would have been excluded. Marine alluvia are mainly confined to the estuaries diverging from the Carrick Roads, which, on the recession of the tide, reveal extensive tracts of mud and clay. The raised beaches are merely expressed by discontinuous shreds still adhering to the present cliff faces. The stream-tin deposits have been worked over so extensively that they are now represented largely by tumbled and disordered ground along the valleys and hollows, many of which are included amongst the alluvial deposits. Blown sand is rare; a patch occurs on the north coast at Porth Towan, and smaller tracts are seen at Pendower in Gerrans Bay. Deposits of "head" are practically restricted to the coastal areas, where they form strips mainly in sheltered bays, with a very small landward extension. Submerged forests are known at Falmouth, Maen Porth, Pendower, and Porthcurnick.

The following table shows the various formations occurring in the area. In the chapters which follow they are successively described in chronological order, commencing with the most ancient:—

Blown sand - - -	Recent.
Freshwater alluvia -	
Marine alluvia -	
Submerged forests -	
Stream-tin and submerged valley deposits - -	Pleistocene.
Head - - -	
Raised beaches -	
Polcrebo gravels -	Pliocene.
Killas, viz., slate deposits:—	
Grampound and Probus series	Lower Devonian.
Veryan series -	Ordovician (Lower Silurian).
Portscatho series -	Lower Palæozoic.
Falmouth series - -	
Mylor series - - -	

IGNEOUS.

Granite.
Elvan (Quartz-Porphyry, &c.).
Mica Trap.
Greenstone.

CHAPTER III.

THE KILLAS.

General Description and Tectonics.

The rock formations that enter mainly into the geology of the sheet are killas. Notwithstanding a general uniformity in the killas or slate formation of this part of Cornwall, it has been found possible to differentiate it into certain divisions. Owing, however, to the practical absence of organic remains, the zones so differentiated are purely lithological. The impersistence of lithological types, added to the advanced stage of decomposition of many inland areas, and the paucity of sections, has in many cases rendered the mapping of definite boundaries impossible. Nevertheless, the demarcation of these rock bands over the area generally has been accomplished with sufficient accuracy for the interpretation of the general tectonic arrangement of the district.

As the extreme plication which has prevailed over the area renders the dip valueless as a stratigraphical criterion, there is still, in the absence of palæontological evidence, some uncertainty as to what is the upward succession.

For the same reason the thickness of the bands defies any attempts at calculation. All that can be said with certainty is that they are immeasurably thinner than their surface indications would appear to indicate, and that the immense thickness ascribed to the killas by the early observers is based on data that are erroneous. The four lithological divisions enumerated below represent the older Palæozoic strata, and succeed one another from east to west in the order named :—

Veryan series.
Portscatho series.
Falmouth series.
Mylor series.

A fifth, the Grampound and Probus series, which represents the newer Palæozoic, departs from that succession and extends right across the area from east to west. The distinctive characteristics of the various groups are as follows :—

Mylor Series.—This series consists of blue argillaceous and fine sandy beds. The latter are often more quartzose than in the Portscatho series, and occasionally a thin quartzite seam is met with. In addition to the more siliceous character of the sandy alternations, the latter are usually of finer texture than in the Portscatho group. The distinguishing feature of this series, however, is its usual striped and ribbon-like appearance, due to very fine interlaminations of siliceous and argillaceous material. In some cases, however, the laminæ are argillaceous only, but of varying composition and colour. This interlaminated character which distinguishes the group is rarely absent, but it is not to be understood that it is confined to this series. It is sometimes seen

in the Falmouth division, and is frequently strongly developed in the Portscatho beds, especially in the district extending from Chacewater to the north coast.

FALMOUTH SERIES. — This series comprises alternations of argillaceous and fine sandy material, varying in colour from green to grey and buff, though occasionally blue argillaceous bands are seen amongst them. The colour, which varies with the character of the sediment, produces the general variegated appearance common to this series. Their mode of decomposition is equally characteristic. The beds become extremely friable, especially those of a sandy nature, are unctuous to the touch, and weather into a deep buff colour. On the whole the material is finer than in the Portscatho series, and the strong grit bands which occur in the latter are absent. Occasionally a narrow zone is seen of purple and green slate, often strongly contrasted, which forms a valuable guide in correlating these beds throughout the district, especially in the absence of the characteristics already described.

PORTSCATHO SERIES.—This consists of blue and grey clay slates, alternating with harder beds, which show every gradation from a sandy slate to a fairly strong grit. The sandy beds are of the same bluish hues as the argillaceous, and are characterised by the large amount of clastic mica which is scattered through them. The great feature, however, which distinguishes them from the Veryan series is the absence of limestone, except at their junction with the latter. This absence of calcareous material distinguishes also the Falmouth and Mylor series.

VERYAN SERIES.—This group, so far as it enters the area of this sheet, consists of blue and grey slate with alternations of sandy beds, thin dark limestones, and dark-coloured cherts, some of which are graphitic. Notwithstanding the occurrence of chert and limestone, the sandy interlaminations are frequently coarse, but are largely made up of soft grains, so that these coarser seams are well cleaved. The series is characterised in this area by the presence of manganese, which stains the slate.

GRAMPOUND AND PROBUS SERIES.—This series consists of fine-grained conglomerates, sandstones, and clay slates. They represent the base of the Devonian, and are distinguished from the underlying Portscatho division by a general calcareous character which never, however, gives rise to limestone, and by a more feeble degree of metamorphism.

NATURAL SEQUENCE OF THE LOWER PALÆOZOIC DIVISIONS.— The Veryan series lies in the western portion of the area coloured as Silurian in the later issues of the old map. The Portscatho series lies immediately next to it, and falls within the area formerly coloured as Devonian. The two groups, however, pass uninterruptedly into one another without any stratigraphical break. Although the appearance within the Veryan series of limestone serves to indicate the apparent incoming of another division of the stratigraphical series, there is no evidence here for drawing a sharp divisional line to mark off two distinct geological formations.

Not only does the Veryan series pass uninterruptedly into the

Portscatho group, but these latter also graduate imperceptibly into the Falmouth series, which in their turn merge insensibly into the Mylor beds. While advantage has been taken of lithological distinctions to separate them into divisions, that represented on the map would explain the stratigraphy, it must be distinctly borne in mind that we are apparently dealing with a continuous series of deposits.

Evidence of Geological Age.—Notwithstanding the comparative absence of palæontological data, the researches of Mr. Howard Fox and other observers on the radiolarian cherts of South Cornwall tend to confirm the conclusions already set forth of the unbroken sequence of these deposits. The radiolarian beds are not always confined to chert, but these organisms sometimes occur in cherty shales. They have been found by Mr. Fox in the cherts of the Veryan series east of Pendower, and near Middle Point, Falmouth, close to the junction of the Falmouth and Portscatho series. Mr. F. J. Stephens* has also described radiolarian cherts from Little Falmouth and other localities in the Penryn Creek, within the Mylor series, which Mr. Fox's researches in that area have confirmed. They have not been observed in the Portscatho series, but the locality near Middle Point, although within the Falmouth series, is only about 35 yards distant from the line adopted as the boundary of the Falmouth and Portscatho groups, which merge almost insensibly into one another, but in the adjoining sheet to the south their presence within the Portscatho series has been detected. Messrs. Fox and Hinde have also found radiolarian beds in North-Eastern Cornwall at the base of the Culm-measures, but the intermediate region, which is mainly made up of Devonian rocks, has hitherto failed to yield radiolaria. That is to say, these organisms have not been detected on any horizons that are known to be of Devonian age. Mr. Fox in his paper† assigns the age of the Veryan cherts to the Lower Silurian (Ordovician) period; the other radiolarian localities at Falmouth and Penryn Creek have been subsequently discovered. The occurrence of chert pebbles in the conglomerate at Nare Point tends to confirm Mr. Fox's hypothesis. The presence of radiolaria in this otherwise barren sequence, and their absence in the Devonian formation, undoubtedly accentuates the divergence between these deposits.

It will be seen in the description of the Probus grits that there is reason to correlate those beds with the well-known conglomerate south of the Helford River, and that both rest unconformably on the Portscatho beds.

The survey of the "killas" area in the adjoining map to the south has thrown much light on the elucidation of the geology of this district. For a detailed account of the evidence the reader is referred to a recent publication by the author.‡ The main conclusions therein arrived at are as follows:—

* *Roy. Corn. Polytechnic Soc.*, 1897.
† *Trans. Roy. Geol. Soc. Cornwall*, 1896.
‡ *Geol. Mag.* 1906, p. 206.

1. The Veryan series includes Quartzite of Lower Silurian age.
2. The Veryan, Portscatho, Falmouth and Mylor groups form a natural sequence.
3. That the evidence favours a descending sequence from the Veryan to the Mylor groups.
4. That these Lower Palæozoic rocks were extensively deformed by earth movements in pre-Devonian times.
5. That the Lower Palæozoics are unconformably overlain by the basement beds of the Devonian.

The evidence therefore at our disposal may be summarised as follows:—The killas divisions occupying this sheet are below the Probus grits and the Meneage conglomerate. The nearest fossiliferous horizon is the Lower Silurian Quartzite, which also underlies the conglomerate. There is no evidence at present for separating any of these killas divisions from the Lower Silurian. The age of the conglomerate has not been definitely proved, but there is a general consensus of opinion that it defines at least the local base of the Devonian. Moreover, its apparent continuity with that formation in the adjoining areas to the north lends support to that conclusion.*

Structures of the Killas.

Before tracing further the local stratigraphy it will be convenient to refer to the typical structures of the killas.

Isoclinal Folding.—A detailed study of the coast sections reveals a complex set of structures that have been brought about as the result of compression. Folds and faults may be

* Sir R. I. Murchison expressed the opinion in 1846 that the killas between Gerrans Bay and Falmouth was of Silurian age (*Royal Geol. Soc. Cornwall*, vol. vi., p. 322). Mr. J. H. Collins published a sketch map with a paper on the "Geology of Central and West Cornwall" in 1881 (*Journ. Roy. Inst. Corn.*, vol. vii., p. 17), in which he marks the killas (included in Sheet 352) as mainly pre-Devonian. Mr. A. Somervail (in the same volume, pp. 262–273) controverts some of Mr. Collins' conclusions, but assigns a Lower Silurian age to the slates from near Penryn to Gerrans Bay, most of which had been similarly classified by Mr. Collins. Mr. Somervail suggested that they were of Llandeilo age. The author, who has been engaged on the survey of West Cornwall since 1897, has always considered these barren strata (Mylor, Falmouth, and Portscatho series) to be linked with the Silurian system, for reasons set forth in the "Summaries of Progress of the Geological Survey from 1897 onwards." (See also papers by J. B. Hill, *Trans. Roy. Geol. Soc. Cornwall*, 1899 and 1901). Mr. Upfield Green has claimed these beds as Lower Devonian, of which the Dartmouth slates represent the upper member, while the base is marked by the conglomerate of Meneage, &c. (*Geol. Mag.*, 1904, p. 403). Mr. Green's conclusions were criticised by Mr. Ussher, who contended that the superposition of the Dartmouth slates to the Mylor, Falmouth, and Portscatho series was not supported by proof (*Geol. Mag.*, 1904, p. 590). Mr. Ussher recalled that although he formerly correlated the Grampound grits with the Gedinnien, he would now hesitate to do so, the inference apparently being that they might occupy a higher horizon. In the map accompanying his previous paper (Roy. Geol. Soc. Corn., 1891) Mr. Ussher has coloured the killas (now representing the Mylor, Falmouth, and Portscatho series) as "(?) pre-Devonian" and has placed the Grampound grits at the base of the series classed as undoubted Devonian. From a persual of his paper it would appear that these particular beds had not been studied by him on the ground, but that his remarks were based on his interpretation of the observations recorded in De la Beche's report. (See pages 32 and 54.) The Lower Silurian Quartzite occurs within the Gorran Sheet, and its included fossils have been determined by palæontologists as Caradoc.

detected immediately in any of the divisions, but as the folds are generally isoclinal, the plication is not so conspicuous as in a region of normal folding. But the evidence of plication is everywhere so marked that the apparent dip can only be interpreted as the inclination of limbs of folds. (Plate IV.) The plication has been accompanied by rock fracture, the faults being almost as numerous as the folds to which they bear a direct relation.

Cleavage.—Under the influence of earth movements not only have the strata been closely folded until relief has been finally obtained from the strains by actual disruption, but the material of which the strata is composed has been also affected. Of the mechanical changes which the rocks have undergone, the most conspicuous are undoubtedly the cleavage planes that have produced the slates. These cleavage planes have been among the last mechanical changes effected by the lateral strains. They traverse the strata independent of the original stratification, and to some extent of the folding in which the stratification has been involved. Although bearing no relation to the original bedding, their disposition in regard to the flexures is more defined, as the cleavage planes show a marked tendency to lie parallel with the axial planes of the folds. When the material so cleaved was originally pure and of uniform consistency, the result has been a perfect slate in which the earlier structures of stratification and folding have been either completely obliterated or faintly preserved by colour banding. Instead, however, of possessing these necessary characters for the production of roofing slate, the killas consists of such an intimate banding of diverse material that the cleavage is subject to marked variations; so that slate of commercial value is rare, and it is doubtful if any such has been successfully wrought in the area under description.

The "killas" being largely made up of alternating bands of diverse texture, its compression has introduced a complex set of structures. Where cleavage has been set up in alternating layers strongly contrasted, such as shale and sandstone, the cleavage planes change their character according to the nature of the layer which they traverse. Those which cross the argillaceous band are not only more numerous than those which traverse the arenaceous layer, but incline at different angles ; so that two shale bands which are divided by a sandstone display parallel cleavage, but this parallelism is broken in the interposing sandstone. Moreover, if the latter is sufficiently massive, it has resisted cleavage altogether, so that we see the phenomena of fissility in perfect parallelism as regards the upper and lower members, while it is absolutely severed by an intermediate band in which this structure is wanting. As the arenaceous beds present every gradation in their texture, there are corresponding gradations in the degree of fissility which they exhibit. Another factor which constitutes a disturbing element is the disruption of the rocks; the fractures produced having acted as planes of relief bringing about a cessation of stresses in their neighbourhood, so that beds of similar crushing strength present different degrees of fissility. In studying the effects of cleavage on the strata of the area the

fact is apparent that flexure, fracture, and cleavage are intimately related, and express different phases of rock deformation. The coast sections display marked variation in the degree of deformation, both as regards the intensity of folding and the nature of the fissility in strata of similar lithological type.

SECONDARY CLEAVAGE, OVERFOLDS, AND SHEAR STRUCTURES.—While the cleavage has resulted merely in the flattening of the component particles of the strata, the rearrangement of material does not always stop at this process, but the crushing to which the rocks have been subjected has set up further interstitial movements. These latter resolve themselves into a succession of small slips along the cleavage planes, and have often been sufficiently pronounced to produce a transverse cleavage which may locally develop to such an extent as to constitute the dominant cleavage of the rock.

In response to lateral pressure the strata have been folded, the flexures have been closely packed together, bringing their limbs into a general parallelism, so that no further relief from pressure is to be obtained by plication. But the strength of the rock sometimes fails before the stresses which still continue to bear, and rupture occurs. The fractures still follow the disposition of the folds and snap their arches, the planes so formed allowing one part of the mass to override its neighbour, and the rock is divided into segments bounded by miniature faults and thrusts.

While the strata on the large scale have been thus modified, their component particles have been undergoing on the small scale precisely the same process which has set up interstitial movements. The individual layers which form the beds have been thrown into a set of minute folds, the arches of which have been broken by tiny cleavage planes which resolve themselves into miniature faults, and there is the same tendency to override as is seen in the larger divisions of the beds. On examination, the rock is frequently seen to be full of such small folds and thrust planes, with a disposition to a secondary cleavage, while minor movement planes appear in the more resisting core itself, with accompanying strain-slip cleavage; and the cleavage planes which pass through the axes of the minute folds often culminate in small thrusts.

PSEUDO-CONGLOMERATES.—Besides the structures already enumerated, these crushing processes, acting on heterogeneous strata, have in this region produced a set of widely distributed breccias which closely simulate the coarser products of erosion. These breccias or pseudo-conglomerates are well developed on the western side of the Carrick Roads, in a belt that extends from Feock to Falmouth; that tract of country is broken by the estuaries which form the creeks of Penryn, Mylor, and Restronguet, along the banks of which they may be conveniently studied.

They consist of slate fragments enclosed within the strata, ranging from the size of peas up to five or six inches in length, with their flat sides lying in more or less parallel planes. As a rule the larger fragments are angular, while the smaller are subangular and sometimes perfectly rounded. They may consist

of either siliceous or argillaceous material, and are identical in composition with the matrix of the slate in which they are enveloped, and from which they have obviously been derived. Instead, however, of being waterworn, as their appearance suggests, they are the products of brecciation. The Mylor beds, in which these phenomena are best displayed, are, as already pointed out, an interlaminated series, in which the thin bands vary in composition. The changing nature of these interlaminations, and the corresponding variation in their limits of compression, have resulted in different degrees of resistance to the crustal movements, the softer beds having easily yielded, while the more resistant strata, separated from each other by bands which are beginning to yield, and being thus deprived of support, are smashed, and the fragments become involved in the more plastic mass. Under the influence of these movements the particles not only become detached from the parent rock, but are frequently so rolled in the process as to simulate pebbles. In tracing the normal laminated beds into the fragmental or brecciated type it is seen that the former gradually lose their regular appearance, and become disturbed by small folds and thrusts, finally culminating in a mass of segments more or less detached, and it becomes apparent that the breccia has originated in little overfolds which have been isolated by small thrust faults. Although direct evidence of this origin is not always forthcoming, we occasionally see, step by step, every stage in the process, beginning with a regular banded rock, followed by minute folding and small thrust planes, partially severing the bands, until at last these processes have not only succeeded in brecciating the rock, but have culminated in the rolling and rounding of the fragments to such an extent that a pseudo-conglomerate has been produced.

This type of rock brecciation has sometimes been brought about without folding; instead of fractures succeeding plication, the stresses have resulted in the direct production of movement planes, which have isolated the fragments from the main mass.

Fractures.—Faults often occur every few yards, both parallel to the strike and in oblique directions, with the result that the whole rock mass when seen in ground plan presents the appearance of a huge mosaic. Over the district generally neither large faults nor deep folds are common. It would appear that at an early stage of the folding process the resistance to the strains was so feeble that fractures were readily produced, and in many districts reversed faults are as numerous as those of normal type.

Relation of Cleavage to Bedding.—Although the rocks are everywhere cleaved, the argillaceous and arenaceous alternations are so numerous that the bedding can usually be detected. Besides the deflection of cleavage in crossing from an argillaceous to an arenaceous bed, to which allusion has already been made, there is a general tendency for the cleavage to cross the bedding somewhat obliquely. The obliquity between cleavage and bedding is not constant. As the cleavage and folding have both been brought about by the same agencies, we see every variation

depending on the character and curvature of the fold, and the obliquity of the cleavage to the bedding will often vary over the different portions of the fold. Although the cleavage is often transverse to the bedding, the general tendency has been for the beds to be thrown into a set of isoclinal folds with a definite general hade, and for the cleavage to cross somewhat obliquely at a low angle. The more the folds depart from this general hade, the greater are the variations between cleavage and bedding. (Plate V.)

Schistose Structures.—Besides cleavage, the slates, as already noticed, are traversed by other structural planes which are analogous to those found in schistose rocks. Indeed, in highly mineralised areas, such as those on the granite margin, the phyllites have often been converted into mica schists, and, given the necessary mineralisation, the bulk of the killas of this part of Cornwall would readily be transformed into typical crystalline schists.

Direction of Stress.—In spite of various exceptions, the constancy of the cleavage dips and the hades of the axial planes is so general over the whole region that there can be little doubt that the later stresses to which the rocks owe their deformation acted from a direction about south-south-east. Over the eastern part of the district, where sections are most numerous, a large series of observations show that the bedding has an average south-easterly dip, and the cleavage, which is somewhat oblique, averages about south-south-east. The most marked deviation from this general dip is seen on the beds that abut on the granite margin between Penryn and Lanner, where the hade is to the north-east. The deflection of the strike here is well brought out by the greenstone masses; and it probably indicates the vertical uprise of the granite column before it spread laterally as a laccolite. Between the granite masses of Carn Marth and Carn Brea and the north coast, the dip is frequently reversed, but this may to some extent be due to the presence of granite underlying the killas at no great depth.

Effect of Superinduced Structures on the General Tectonics.—Owing to the folded nature of the killas, the various lithological divisions, instead of occupying well-defined areas, tend to encroach on one another, and lenticles of one division are commonly found in the adjacent group. This is more especially the case as regards the Portscatho and Falmouth groups. The Veryan series occupies but a very small tract on the eastern part of the sheet to the north of Gerrans Bay. The granite masses of Carnmenellis, Carn Brea, and Carn Marth that are entirely enveloped by the Mylor series, are lying in a major fold which dies out to the north-east in the vicinity of Truro. The Falmouth and Portscatho groups, in spite of irregularities due to lenticular inclusions previously referred to, sweep round this irregular curve of the Mylor group, from the north-west coast to the south-east coast, and occupy between them not only most of the northern part of the map, but the greater portion of the eastern area lying beyond Truro and the Carrick Roads. If, as appears probable, the

Veryan series represents the top of the sequence, the major fold would be an anticline.

The characteristic structure of the district is well illustrated in the area between Falmouth and Truro. Here, although we are apparently crossing the strike from the coast to the heart of the county with a steady south-easterly dip, yet instead of getting deeper in the stratigraphical sequence, we are on precisely the same geological horizon at Truro as at Falmouth, the intervening ground being made up of a succession of isoclinal folds.

The general features of the killas having now been described, the two succeeding chapters will be devoted to a brief sketch of the distribution and field relations of the various divisions, together with any local points of interest that they present.

CHAPTER IV.

LOWER PALÆOZOIC.

I. Mylor Series.

This division of the killas occupies a large area on the south-western portion of the map. It encloses the granite masses of Carnmenellis, Carn Brea, and Carn Marth, the various greenstones, together with the greater portion of the elvan dykes. It contains, moreover, in conjunction with the granites, almost the whole of the mineral lodes. The group, therefore, has not only been metamorphosed by the granites for large distances from their margins, but has been fissured to a much greater extent than the other divisions, and has over large tracts been impregnated by mineral solutions that have affected the nature of its decomposition. This is especially shown by the iron oxide with which it has often been richly charged, and by the amount of vein quartz that is frequently so abundant as to impoverish the soil. This group, which is succeeded by the Falmouth series, contains few infolds of that division, in striking contrast to the Portscatho beds. In the area between Perranwell and Falmouth, beyond the limit of the granite aureole which is here of slight extent, the group is seen in its normal condition, lying outside the tracts of important mineral alteration. This district, therefore, will be described first.

As pointed out in a previous section, this division is essentially an interlaminated series, in which the ribbon-like structure is often modified by brecciation, that has been set up by the stresses which have folded, cleaved, and fractured the killas. This minute type of brecciation presents every variation: from beds in which the fragments are rare, to others in which this structure so far predominates as to pervade the whole rock mass. This superinduced structure, however, instead of producing a rock of incohesive type, has generally had just the opposite effect, so that the series, notwithstanding its broken condition, has a more homogeneous and massive appearance than the less heterogeneous Portscatho group.

These beds are exposed along the shore of Falmouth Harbour from Arwenack to the Penryn Creek. In the section between the piers at Market Strand and Greenbank they are of the brecciated type, in parts so coarse that some of the fragments exceed 2 inches in length. As the stone has been largely utilised for building purposes, the structure of the Mylor crush breccias can be admirably studied in the blocks contained in the walls and buildings. The railway cuttings between Falmouth and Penryn also afford sections of the different phases of the Mylor series. The cutting, for instance, between Kimberley Park and Penmere, shows these slates dipping south-east, with fine pale coloured siliceous partings, and brecciation in its initial stage. The cleavage is regular, and traverses the bedding. Similar beds, but without brecciation, are seen in the cutting at

Tregenver. The partings, when of a siliceous character, give a massive character to the section. The rocks are frequently very dark in colour, and must contain much carbonaceous material, as in the railway cutting north of the bridge near Trescobeas. Frequently the beds are purely argillaceous.

Good sections are exposed along the Penryn Creek, at the upper portion of which the dips frequently change their direction. Between Boyers Cellars and Tehidy Terrace, and also on the north side of the creek, the brecciated type is seen, and when fine sandy beds alternate with argillaceous, the folding is at once apparent. On the north side of Greenbank Quay typical brecciated beds, with fragments from 2 to 3 inches in size, are succeeded by banded slates in which the dark and pale layers are from 2 to 3 inches thick. In the same vicinity two outcrops of fine-grained greyish-blue quartzite occur, about a foot in breadth.

The old quarry adjoining the High Street at Flushing has been worked in brecciated Mylor slate. It is a coarse, massive detrital rock, in which the fragments are angular, sub-angular, and rounded, and range to an inch in size and even larger. The individuals are of argillaceous or of fine-grained quartzose material, and the matrix is massive. The rock has been subjected to movements and is highly disturbed, and even on the small scale minute puckering is general. The cleavage planes usually curve round the fragments but traverse some of the argillaceous individuals.

The coast between Flushing and Trefusis Point affords an excellent dip section that is more or less continuous and easily accessible. Commencing at Wheal Clinton, brecciated slates appear in which fragments of slate, some dark in colour, are embedded in a pale greyish-green matrix. These are succeeded by very dark argillaceous slates, in which the striping, although visible, is of a very fine character. This dark, carbonaceous-looking rock is replaced about 150 yards west of the quay by striped grey and blue slate much fractured and disturbed, with some quartz veining. East of the quay these fissile beds are succeeded by greenish bands, rather massive, and containing the pebble-like fragments due to brecciation. These again are replaced by hard slates, much faulted, and veined with quartz, in which small pebbly beds occasionally appear. At Trefusis Point fine sandy bands alternate with blue argillaceous slates, and striping is conspicuous, especially in the latter. The sandy beds frequently reveal the isoclinal folding. The cleavage-dip along the whole section is to the south-east, varying from 30 deg. to 45 deg., but minor faults and folds are so numerous that the dip is most inconstant. On the shores of Mylor Creek the brecciated beds or pseudo-conglomerates are well seen, alternating with more argillaceous zones in which this structure has not been developed. On the north side of that creek, and about one-third of a mile south-east of Mylor Bridge, the beds have an unaltered appearance, and contain a seam of massive mudstone 2 or 3 feet in thickness. This, submitted to microscopic examination (3,573) proves to be a fine micaceous shale, with very small angular

fragments of quartz, scales of mica, and dark carbonaceous streaks, which give the rock a well-defined bedding.

The quarry at Enys presents a good illustration of the interlaminated character of the Mylor series, where it has not been subjected to the brecciation that has evolved the crush conglomerates. The slate is very massive, and coarsely striped; the cleavage and bedding planes both hade to the south-east, the former at 45 deg., and the latter at 25 deg. It consists of alternations of pale and dark material, the latter being always argillaceous, while the former varies from argillaceous to siliceous. The pale bands predominate, and are often half an inch in thickness. This composite structure enables the fractures and folds to be readily detected. The brecciated structure is absent, but where the pale laminations are severed by small shear planes the first stage in the process has been set up.

The pseudo-conglomerates are conspicuously developed along the southern shore of Restronguet Creek. Commencing at Weir Point, the slates are brecciated. Below Weir Villa thin bluish argillaceous rocks enclose flattened lenses of rather harder materials, but the slate here is fairly homogeneous, without bedding planes. A little further west, just before reaching Post, a brecciated structure appears, which is more pronounced, however, in the vicinity of faulting. To the west of Post, and immediately opposite Restronguet Point, the slate is massive and homogeneous, with a cleavage dip of 35 deg. to east-north-east. A little further up the creek the beds are well striped, both in thin laminations and in coarser seams an inch in thickness, of pale argillaceous, alternating with dark seams. Brecciation here is slight, and the mass is fairly homogeneous. The cleavage, which is still in the same direction, crosses the bands at all angles. The massive blue slates with occasional striping, and often studded with cubes of pyrites, continue to the Ship Inn. At the quay similar beds occur with a low cleavage dip to east-north-east, and are striped. The dominant cleavage here is often at right angles to the bedding, which is puckered, while the cleavage planes are regular. The quartz veins, moreover, have shared in the folding. In the neighbourhood of a fault, carrying a quartz vein, 1 foot in thickness, brecciation again appears.

The striped slates, much disturbed with faulting and folding, can be followed along the shore to the bay below Tregunwith, to the south of which some greenstone bands and an elvan occur, all in a highly decomposed condition. On the north side of this bay the interlaminated character of the beds is pronounced. The dip is irregular, as the bands are much folded. These contorted zones alternate with others of regular hade, but the former predominate. Occasionally bands with brecciated slate appear about a foot or so in thickness, the isolated fragments being clearly due to rock fracture. These pseudo-conglomerates soon get more conspicuous, but are still subordinate to the normal rock type.

At Restronguet Point the coarse brecciated structure is exceedingly well developed. (Plate VI.) Fragments up to an inch

or more in length are profusely scattered in a darker matrix. Amongst the argillaceous beds thin gritty seams are observed, in which deformation has commenced. The killas here has been so involved in these movements that in many places the entire rock mass has undergone mechanical reconstruction. The structures are analogous to those of schistose rocks, but have stopped short at these mechanical processes. Chemical changes have, however, been initiated, as in many parts of this section the slates have been converted into phyllite, with micaceous lustre clearly defined. The brecciated structure is most pronounced where the fragments are of a quartzose nature, as being less flattened they protrude from the rock surface. Some quartz veining occurs in the section which has been involved in the folding. Occasionally a coarser bed occurs revealing the dip; these limbs, however, are generally parallel to the dominant cleavage. On the side of Restronguet Point fronting the Carrick Roads numerous small faults, slightly oblique to the strike, are seen to repeat the beds. Indeed, the whole section proceeding north along this coast is of a most disturbed and plicated character, consisting of a series of segments and lenticles that have been torn from the original homogeneous mass. In this brecciated series there are, nevertheless, some zones in which such deformation is absent. This is seen about 200 yards north-east of Restronguet Point, where the undisturbed seam is a hard, dark arenaceous bed. The disrupted condition of the section, as well as its re-duplication, is clearly illustrated by a quartzite seam which occurs along the coast for a distance of about a third of a mile from Restronguet Point. This quartzite is about a foot in thickness and is probably related to the quartzite already referred to, at the entrance to Penryn Creek, near Greenbank Quay. It is rather dark in colour and is often associated with much vein quartz. The quartzite, instead of forming a continuous seam, is represented by a series of detached lenticles, some of which are several feet in length. At its most northern exposure the quartzite has been folded on itself, causing thickening, but in places the limb thins out entirely. The "head" which fringes the shore here contains at its base some lenticular blocks of quartzite about three feet across.

A quartzose band from Carclew, a specimen of which was sliced, shows under the microscope (3,389) fragments of organisms which Mr. E. T. Newton believes to be pieces of much altered echinoderms, perhaps crinoids. Dr. Flett considers that the rock has the appearance of a modified chert.

From Restronguet Creek the Mylor beds swing round to the north-west of the map, as already indicated, in conformity with the Falmouth and Portscatho groups, the Mylor beds forming the inner zone. From Restronguet Creek they extend to Carrine Common, near Truro, whence they curve round to the west through the districts of Baldhu, St. Day, and Scorrier, to Stencoose and Mawla. Thence they follow a south-westerly course through the parishes of Redruth, Illogan, and Camborne. From Camborne they extend southwards through the districts of Crowan and

Breage, occupying the area between the margin of the Carnmenellis granite and the western edge of the sheet. Over the greater part of the area between Baldhu and Camborne they are highly decomposed, their surface débris being stained deep red and various shades of buff by the iron oxides with which they are frequently charged in the mineral area. In the south-western portions of the sheet, however, in the parishes of Breage and Sithney, this discoloration is comparatively rare, and the rock is often extremely fresh at the surface. That part of the Mylor series which more immediately fringes the granite masses will be treated separately in the section dealing with the contact metamorphism produced by those granites.

Mr. F. J. Stephens* has recorded various localities between Trefusis Point and Penryn where radiolarian cherts occur. These have since been supplemented by Mr. Howard Fox.† The micro-sections were submitted to Dr. G. J. Hinde, who determined some of them to be full of radiolaria, although the rock shows evidence of great distortion.

II. Falmouth Series.

On the southern side of Falmouth a strong band of this series extends from the Pendennis peninsula to Swanpool and Penrose. From the latter locality to Carlidnack it contracts, but widens again in the neighbourhood of Mawnan Smith, where it is continuous with a band that reaches the coast between Maen Porth and High Cliff. It can thus be demonstrated that the Falmouth and Maen Porth bands, separated by the Portscatho slates between Pennance Point and Maen Porth, are in reality a single unit repeated by folding. The coast between Swanpool and the vicinity of the Falmouth Hotel presents an excellent section of this group, and was described by De la Beche as a variegated series.‡ The prevailing blue colour of the adjoining Portscatho group has been replaced by tints that vary from green to grey and buff, although blue argillaceous bands are still to be seen amongst them. The deep cliff sections, moreover, frequently display a reddish hue from the presence of iron oxide. The strata consist of alternations of argillaceous and fine sandy material, the colour varying with the character of the sediment; hence the general variegated appearance of the series. The weathering is equally characteristic; the beds become extremely friable, especially those of a sandy nature, and assume a deep buff colour. Lamination is sometimes conspicuous, thus linking them with the Mylor beds on the north-west. Although there is a general dip to the south-east, the section shows a high degree of disturbance. The amount of minor contortion and fracture is such that a most confused section is the result, and this is accentuated by the presence of much quartz veining. Within this series a small zone of sharply contrasted purple and green slate is seen in the large dry

* *Royal Cornwall Polytechnic Society*, 1897, p. 104.
† From unpublished information furnished by Mr. Fox.
‡ "Report on the Geology of Cornwall," &c., p. 93.

dock at Falmouth. Three purple bands, one of which is 10 feet in thickness, are separated by green slate.

On the eastern side of the Carrick Roads an infold of the Falmouth series occurs within the Portscatho beds. It forms a strip skirting St. Mawes Harbour between Castle Cove and Polvarth Point. Here the buff beds seen at Falmouth are practically absent, and the rocks are distinguished from the adjacent Portscatho group, into which they insensibly merge, by pale greenish hues, which not only pervade the killas but also occur occasionally amongst the quartz veining. Like the band, however, at Falmouth, the slaty beds here contain the characteristic purple and green zone, which is exposed at Castle Point, and again on the shore to the north-east of the quay at St. Mawes. The section between St. Mawes and Polvarth Point illustrates the constant repetition by folding. Being transverse to the strike, the various fluctuations in the plication are brought out, and notwithstanding that the beds are often nearly horizontal, with slight undulations as exhibited by the harder sandy bands, the prevailing dip of the various limbs, whether regular or contorted, is to the south-east.

Further to the north a band of variegated buff and green beds occurs at St. Just Creek. They are much crumpled, and in places show small thrusts from the south-east. About half a mile north of Messack Point the typical purple and green slates form a small belt, into which a mica trap has been intruded. Another band of the Falmouth series occupies a strip running nearly south to the coast from Camerance Wood, where purple and green slates are exposed. Near Turnaware Point a band occurs containing purple and green beds, pale greyish green slate, and some of the buff beds. From the amount of plication exhibited there can be little doubt that they represent isolated lenticles due to folding. To the west of Philleigh, a band which passes through Polmesk can be traced by the purple and green slate, both in the solid condition and as surface débris. Between Ruan Lanihorne and Philleigh an extensive strip of Falmouth beds occurs in which the sandy buff beds predominate, but the purple and green bands have not been noted. Along this comparatively low-lying land they disintegrate more rapidly than the Portscatho group which they adjoin, and thus form a deeper soil, as can be well seen at the promontory at Ardevora Veor, which stands higher than the land further east; the former being occupied by the Portscatho series and the latter by the Falmouth beds. The lenticles that occur still further east, at Trenestrall and Treworga, are characterised by the typical buff beds, but as they appear to be intermixed with some Portscatho slate the boundaries drawn are necessarily general. Between Merther and Trevervoe buff beds of this type occur infolded with the Portscatho group, but whether they form a continuous band or consist of a line of lenticles the evidence is insufficient to show. The infolds of this group amongst the Portscatho series between the Truro River and Feock call for no special comment; they consist of the usual variegated and buff beds of this series. At Malpas, however, the Falmouth beds are

associated with some of the greenish and purple bands that still further define the horizon.

We will now more particularly refer to the occurrence of the Falmouth beds on their true geological position, separating the Portscatho from the Mylor group. Their position at Falmouth between those groups has already been referred to. These marginal relations are then broken by the estuary of the Carrick Roads, at the head of which, in the district of Feock, the geological sequence, represented by the Mylor, Falmouth, and Portscatho groups, sweeps round in a big curve to the north-west, the apex of which lies in the neighbourhood of Truro. This great fold, is, of course, complicated by the general isoclinal plication and accompanying fracture that has involved the whole area. In spite of this disturbing element, however, the larger fold is sufficiently brought out by the mapping, showing an inner ring of Mylor beds partially encircled by the Falmouth and Portscatho groups respectively. Notwithstanding this generalisation, however, the marginal lines are necessarily irregular, on account of the disturbing elements already referred to. Thus the subdivision of the killas is often a matter of great difficulty, owing to the impersistence of lithological types, and in some cases to their close resemblance to one another. Not only do the Portscatho and Mylor groups sometimes shade into types that are practically indistinguishable, but the Falmouth group which divides them, and on the whole exhibits a stronger lithological contrast to either, is not always persistent in character. Nevertheless, the correct identification of the Falmouth group furnishes the key to the interpretation of the major geological structure of the area. Notwithstanding the many fluctuations in lithological condition exhibited by this series, the Falmouth beds are evidently much thinner than the Mylor and Portscatho groups which they separate, so that in some areas, where the surface geology is obscure, they either cannot be identified at all or their recognition is attended with much uncertainty. In mapping this group, however, the presence of the purple and green zone in any recognisable form is of the utmost value, and fixes the horizon with precision. So far is this the case that a band of this nature, however narrow, and unaccompanied by the more general buff and decomposing strata of Falmouth type, would be confidently interpreted as unmistakable evidence of the geological horizon.

The Falmouth beds will now be briefly described in their passage round the great fold in their relation to the Portscatho and Mylor groups which they divide. In the neighbourhood of Feock and Restronguet Creek, although all three groups are in close proximity, their boundaries seem to be marked by north-westerly faults, the evidence of which is clearly seen along the banks of that creek. Between Porthgwidden and Restronguet Point a fault is seen with three or four feet of vein breccia, which apparently brings the Mylor and Portscatho beds in juxtaposition. On the north side of Restronguet Creek a strip of the Falmouth beds fringes the coast for about half a mile, extending as far north as Pen Poll Creek; it succeeds the Mylor beds, but its relations to the

Portscatho group are not seen. The Falmouth beds are not again recognised between this and the north of Carnon Downs, near Killiganoon, and if they occur can only be feebly represented. They are probably cut out by a fault extending from the north side of Carnon Downs to the south side of Feock Downs. In this band they are far from typical, and good sections are rare. Between Killiow and Truro the band cannot be satisfactorily followed owing to the absence of sections, and to some extent also to the nondescript character of the rocks. In the neighbourhood of Truro this group is strongly represented by deep sections of the characteristic bright buff beds, highly decomposed, that alternate with the fresher and more solid blue slates of the Portscatho group. The irregularity of the outcrops at Truro is due to the nose of the major fold acting on the close isoclinal plication, and to the broken nature of the topography represented by the extensive valleys that radiate from that centre. From thence to Chacewater the band extends in a westerly direction; it is necessarily very generalised, and contains portions of the adjacent groups which cannot be separated. Over a great part of this belt the country is flat and practically devoid of sections, more especially in the district lying to the north of Chacewater. Moreover, the mineralisation in these metalliferous areas has contributed to obscure the nature of the killas. Here and there, however, traces of the purple and green zone have been noted. Purple and green detritus is also seen at Creegbrose, and between that locality and Greystown. On a mine burrow at Cox Hill, just within the Mylor group, some large blocks of purple and green slate were observed that had apparently been raised from the mine. Moreover, De la Beche records the occurrence of this kind of slate in the mines at Gwennap.* So far as it goes, therefore, this might be taken as evidence of the superposition of the Mylor beds to the Falmouth group, and that the sequence from the Mylor series to the Veryan beds may be a descending succession, but the area is too folded to warrant such a deduction. Perhaps the best section of the Falmouth beds in this locality is that formed by the road cutting at Green Bottom, on the north side of Saveock Water. Between Blackwater and Parsley they have not been detected, a fact due perhaps to the paucity of sections, but they may possibly have been cut out by the fault that meets the coast at Porth Towan. From Parsley, however, to Reskajeage Downs on the north coast, and to Treswithian Downs, the purple and green beds are abundantly developed, and the zone has been traced by Mr. Dixon between the Mylor and Portscatho groups.

The purple and green hues so characteristic of this formation are well exhibited in the north-western region in the cove south of Gullyn Rock, in quarries between the latter and North View, and in the cliffs facing Reskajeage Downs. Inland the colours are seldom clearly seen, so that the boundary between these slates and those of the Mylor beds is not well defined.

The sole organic remains at present known from the Falmouth beds are the radiolaria, discovered by Mr. Howard Fox, near

* Report previously cited, p. 93.

Middle Point, Falmouth, to which attention has already been drawn.

III. Portscatho Series.

This series immediately succeeds the Veryan group in a westerly direction. Its principal distinguishing feature from the latter is the total absence of limestone, except at their mutual junction. Although the coast line south of Pendower forms the boundary of this series, yet small calcareous layers, linking it with the Veryan group, are seen along the shore as far south as Creek Stephen. The true boundary between the two divisions possibly includes a little of this southern coast line. The natural transition between the Veryan and Portscatho types along the shore between Pendower and Creek Stephen Point is sufficiently attested by the gradual dying out of the limestone. Excellent cliff sections of the Portscatho series are exhibited between Gerrans Bay and the Zoze Point. Estuary sections of shallower depth are continuous for several miles along the various creeks converging to the River Fal and the eastern side of the Carrick Roads. On the north coast this series can be studied along the shore for at least four miles between Porth Towan and Reskajeage Downs.

The section between Pendower and the Zoze Point admirably illustrates the disturbed nature of the killas. The beds are frequently wavy, while the sandy seams reveal the curving and nosing out of folds. Faults often occur every few yards, and even feet: either of normal type coincident with strike or dip, or small reversed faults or slides hading at a low angle. They appear to have but small throw, often being limited to a foot or so. The picturesque caverns which make a feature of this coast have been formed along the strike faults. Vein quartz is often very abundant, and has frequently shared in the folding. Here and there the argillaceous beds show striping like that seen in the Mylor series. In the neighbourhood of faults the clay slates sometimes take on a phyllitic aspect. Notwithstanding the general south-easterly dip, the coast is so broken by faults that there are numerous deflections, both as regards direction and hade, beds comparatively flat being closely adjacent to those highly inclined; others, again, with even bedding, are sharply succeeded by strata highly contorted. The Shag Rock at St. Anthony Head affords an excellent section of the constant repetition by small folds and faults hading to the south-east. At the Lighthouse, although the individual beds are folded, there is a steady cleavage dip.

The Portscatho beds from the St. Anthony peninsula reappear at Pendennis Point on the western entrance of the Carrick Roads, and are seen also on the Black Rocks which project at low water at the mouth of the harbour. At Pendennis Point they occupy a strip about a third of a mile wide when they merge into the Falmouth beds. The Pendennis section is a repetition of that of St. Anthony, being made up of fairly hard, wavy, argillaceous slates, with sandy alternations.

There is a moderate amount of vein quartz, and small faults are numerous, especially those following the trend of the strike, along which gullies, locally known as "drangs," have been excavated on the coast. This band, after crossing Falmouth Bay, re-emerges close to Pennance Point, and is admirably displayed on the coast section from thence to Maen Porth. At Pennance Point the beds are fairly free from contortion. They are hard, and of the nature of fine arenaceous slate, being well cleaved, with regular linear striping, but without the conspicuous sandy alternations. Between Sunny Cove and Newporth Head the typical dark blue argillaceous slates reappear, with a dip of 48 deg. to the south-east, and a cleavage dip of 60 deg. in the same direction. (Plate VI.) At Newporth Head the finely quartzose beds recur with a brown weathering, and producing an uneven rockshelf.

On the eastern side of the Carrick Roads the continuity of the Portscatho series is broken by no less than five infolded lenticles of the Falmouth beds, and others occur south of the River Fal between Ruan Lanihorne and Philleigh. The tract between the River Fal and the Tresilian River is almost entirely confined to the Portscatho group, except for a strip of Falmouth slate between Merther and Trevervoe. West of the Fal several infolds of the Falmouth beds occur between Truro and Feock.

In this broad tract between Truro and Gerrans Bay the constancy of the dips of both cleavage and bedding in a south-easterly direction is well marked. Notwithstanding contortion and small faults, which are as frequent as on the coast section at Gerrans Bay, it is unusual to find the dip reversed. In spite also of the fractured nature of the district, as indicated by the innumerable small faults, there is no evidence in this wide tract of the existence of faults of sufficient magnitude to be shown on the map. It is true that the uniform nature of the strata is unfavourable for their detection, but the many miles of section afforded by the estuaries would be expected to reveal fault breccia if fractures of any magnitude were present. Moreover, the absence of elvan dykes and mineral lodes, tends to confirm the conclusion that fissuring on the large scale is not prevalent in this district.

The killas, which is so frequently decomposed in inland sections for some depth from the surface, presents in some localities exposures that are singularly fresh. This is especially the case in the parishes of St. Michael Penkevil, St. Clement, and Merther. The Portscatho beds usually weather to different shades of brown, but in the mineral areas, like the rest of the killas, they frequently become deep red from the oxidation of the iron ores, and shades of rich buff and even very pale whitish grey are also common.

At Governs, about 2½ miles west-north-west of Truro, some very massive greenish slate is seen in a quarry. The massiveness of the rock is due to its silicification, which takes the form of fine interlaminations of quartz between the argillaceous folia that at first sight suggest original bedding, as they share in the undula-

tions of the rock. But the silicification has followed the folding, although it has taken advantage of the lamination with singular regularity. At times, however, patches of phyllite are seen entirely enclosed by quartz, while isolated quartz fragments point to a certain amount of brecciation. As this quarry occurs in the vicinity of abandoned mine workings, it is possible that the unusual green hues are due to secondary mineralisation. Still further to the westward, between Croft West and Treveskas, some of the Portscatho sandy beds are similarly tinted with a greenish hue, but this is also in the vicinity of a mineral lode, and a little of the argillaceous rock exhibits tiny knotting. Thence to the westward the mineral area has been reached, and the reddening of the surface rocks is a common feature. Moreover, this coloration is sometimes accompanied by greenish hues, which, beyond the area of mineralisation, would have led to the supposition that the débris was derived from Falmouth beds.

Within the mineral region the evidence of colour is no longer a safe criterion in mapping the lithological divisions, and has to be used with caution. Thus, large tracts of the mineral area lie in comparatively flat country, buried under a covering of decomposed rock or débris, which is variously coloured by iron oxides, as in the area surrouuding Chacewater, Blackwater, and Skinner's Bottom. In these districts, however, the contents of the mine-burrows often afford good evidence of the nature of the underlying killas. For instance, to the north-west of Carnhot, where the surface débris is often of a red and greenish tint, the mine tips show the solid rock to belong to the Portscatho group, though often very pale in colour, due to bleaching. Occasionally, however, the argillaceous members are more interlaminated than in the typical areas. Further to the west, in the district of Blackwater, the evidence of the burrows shows this interlamination to be a common feature, and it retains this characteristic in its westerly extension to the north coast. The depth of the decomposition and mineral staining is well seen in the cuttings of the new railway connecting Chacewater with St. Agnes. The cutting at Blackwater affords a vertical section from 12 to 20 feet deep, in which the sandy and argillaceous beds are stained deep red for the entire depth of the exposure. In spite of the obscurity caused by this soaking in iron oxide, the resemblance to the Portscatho type is sufficiently retained, while folds and small faults are often seen. The red staining is sometimes replaced by buff hues. The fault planes contain little quartz, but are often richly charged with hematite. The reddened slate, moreover, sometimes suddenly ceases, and is succeeded laterally by bluish slate, in which the upper surface is often of a buff colour for a depth of 2 or 3 feet. Some of the fine bleached arenaceous beds readily crumble into a clay-like substance.

Mr. Dixon has observed that the Portscatho series of Porth Towan pitch to the south-west, and disappear in that direction beneath the Falmouth beds. Along the northern margin of the Portreath mass the cleavage generally inclines north-north-west,

while north-east of Portreath the folds are generally inclined to the south-south-east. In the cliff south of Gullyn Rock, and beneath Tregea Hill, slides of different inclinations intersect, and the steeper faults hading south disturb the others, which incline to the north. At the latter locality the later faulting is clearly of normal type.

The most conspicuous cross courses seen along the northern coast are as follows: Cliff, south-west of Tobban Horse (2); Cove, south of Gullyn Rock (1); Cove, south of Gooden Heane Point (2); Porthcadjack Cove (1). With the exception of one of those occurring at Tobban Horse, they all hade to the west. Their throw is not known; they are accompanied by thick vein quartz, and most of them discharge water. A little iron, lead, and copper staining is the sole indication of their metalliferous contents. In several cases valleys have been eroded along lines of fault.

Along the northern edge of the map this division of the Lower Palæozoic group is unconformably overlain by the Probus series of the Lower Devonian formation, and their marginal relations are described in the chapters devoted to the latter.

Under the microscope the Portscatho slates show no characteristics of special interest. The argillaceous seams can be seen to contain minute grains of quartz, together with films of biotite and muscovite (3,392). Sometimes, besides cleavage, a well-defined parallel structure representing bedding is seen, and there is occasionally minute brown staining, due to iron oxide (3,574).

The grit bands are principally composed of quartz, mica, and slate fragments. Felspar also occurs, but in small quantity as compared with quartz.

The small dark concretions of nodular form that are often scattered in the slate are quartzose lenticles, consisting chiefly of very finely granular quartz with a few larger grains, and only imperfectly cleaved.

Mr. J. H. Collins has recorded the presence of corals at Lower Newham, in the neighbourhood of Truro. The late Dr. P. M. Duncan, to whom he submitted specimens, suggested that the markings on the surface of some of the schistose planes resembled infiltrated corallites of a genus like *Favosites*, and concluded that it was probably a metamorphosed coral.*

The siliceous schist containing these suggested coralline markings was analysed by Mr. Collins, with the following result:—

	a.	*b.*
Silica - - - - - - -	66·81	69·88
Ferric oxide and alumina - -	27·21	23·28
Magnesia - - - - - -	·75	1·17
Lime - - - - - -	·08	·15
Phosphoric acid - - -	trace	—
Moisture - - - - -	5·62	6·11
	100·47	100·59

* *Journ. Roy. Inst. Cornwall*, vol. vii., p. 31. Messrs. Upfield Green and Sherborn, however, regard the structure as inorganic.

Mr. Collins suggests that the low percentage of lime is due to change in chemical composition since the formation of the rock.*

Mr. C. W. Peach found part of the stem of an encrinite at Truro, in a quarry near the Patent Wood Works, where he also observed other indistinct fossiliferous marks.†

IV. Veryan Series.

This group is restricted on the map to a triangular tract of about half a square mile lying to the east of the valley connecting Pendower and Crugsillick. An excellent section is afforded by the coast of Gerrans Bay, extending from Pendower to the eastern margin of the sheet. It is composed mainly of dark slate, with subordinate sandy seams, but it is especially characterised by the presence of limestone and chert. These members, so heterogeneous in type, are closely associated; slates, sandstones, limestones, and chert occurring together in a limited section. The sandy beds, moreover, are frequently coarse, but shale fragments enter largely into their composition, so that they readily cleave. The limestone‡ occurs in thin bands, ranging from a few feet to a few inches in thickness. This section has been described by Mr. Howard Fox,§ who states that the limestones increase in thickness and frequency towards the eastern part of the section, which our examination confirms. A little to the east of Pendower the limestone is represented by a few thin seams, which westward become still more attenuated as they are traced within the Portscatho series, where they soon die out altogether, the calcareous zones forming the connecting link between the two groups. The limestones, although containing organic fragments, have failed to yield recognisable fossils. The chert beds on the western part of Pendower Beach have been figured in the work already cited by Mr. Fox, who states that black chert is there seen interbedded with shales on the foreshore and also at the base of the cliff, which is "occasionally composed of black chert several feet thick, at other times of chert sheared into thin bands, which are more or less disturbed." In one place Mr. Fox observed the apparent passage of chert into quartz, and he states that "black chert occurs at intervals in the foreshore and cliff for more than 1,000 yards eastward," and gradually becomes thinner and less frequent, as well as more impure and decomposed. This decomposition was attributed by Dr. Teall to the decay of pyrites crystals, which the microscope shows to be present in the chert. Micro-sections of the chert examined by Dr. G. J. Hinde reveal indications of radiolaria with marked signs of shearing. In the shales associated with the chert crinoidal remains have been found. The Veryan beds yield appreciable quantities of manganese in association with oxide of

* *Journ. Roy. Inst. Cornwall*, vol. vi., p. 418.

† *Trans. Roy. Geol. Soc. Cornwall*, vol. vi., p. 181.

‡ These limestones were described in 1818 by Mr. S. J. Trist and the Rev. J. Rogers. *Trans. Royal Geol. Soc. Cornwall*, 1818, vol. i., pp. 107 and 114.

§ *Trans. Roy. Geol. Soc. Cornwall*, 1896.

iron, which occur along the divisional planes. Near the western end of the section the slates are studded by circular bodies, some of which attain half an inch in size; a specimen, tested by Dr. Flett, consisted mainly of impure limonite, with little or no manganese. They are surrounded by a thin periphery of quartz, and, owing to the weathering of the decomposed core, they are frequently represented by cup-shaped hollows lined with quartz. Considering the disturbed state of the slates and the absence of distortion in these spherical bodies the latter are not likely to be organic. Below high-water mark the slates are very dark in colour, at times almost black, while the bulk of the sandy alternations are of a pale colour and therefore strongly contrasted. In the cliff sections, however, where the beds are more decomposed, the weathering of the slates exhibits strong colour contrasts, some parts being pale yellow and brown, while seams a foot or more in thickness of rusty brown material probably indicate beds charged with manganese and iron oxide, the varied colour of the phyllite being doubtless due to the presence of these oxides in a less concentrated form. A quantitative analysis of the manganiferous band undertaken by Dr. Pollard revealed the presence of a small quantity of carbonate, in addition to manganese and iron, and manganese is in excess of iron.

While the general dip of the beds is to the east, they are frequently lying at a very low angle not far from the horizontal, with gentle undulations, so that their thickness may be slight notwithstanding a considerable breadth of outcrop.

Mr. J. H. Collins has published an analysis of the limestone.* He describes it as "a very dark-coloured rock, occurring in narrow bands in the dark slate of Gerrans Bay. It contains microscopic organisms in abundance," some of which are fragments of encrinite.† The analysis is as follows:—

Silica	6·67
Alumina and ferric oxide	2·55
Magnesia	1·71
Lime	43·45
Phosphoric acid	traces
Carbonic acid	39·42
Moisture	5·69
	99·49

* *Journ. Roy. Inst. Cornwall*, vol. vi., p. 419.

† *Trans. Geol. Soc. Cornwall*, vol. x., p. 5. Mr. J. H. Collins "On the Stratigraphy of West Cornwall."

CHAPTER V.

DEVONIAN ROCKS.

Grampound and Probus Series.

This series, consisting of fine-grained conglomerates, sandstones, and clay slates, is slightly calcareous. and is equivalent to the Manaccan series that occurs in the adjoining map to the south of the Helford River, except that in the latter locality, besides the fine-grained conglomerates like those of Probus and Grampound, these beds frequently attain an extreme coarseness, many of the included boulders exceeding a foot in size. The conglomerate in that area is by no means continuous, but the base of the formation is frequently of fine texture. There is, moreover, a tendency for the coarser conglomerate to die out in a westerly direction, so that the demarcation of the Manaccan series from the older Palæozoics is attended with difficulties in the cultivated areas. These conditions are exactly reproduced in the Probus beds, the coarse conglomerates, analogous to those of Manaccan, occurring only in the Gorran district to the east of this map, while in a western direction towards the coast of the Bristol Channel the fine-grained conglomerates of Probus disappear. The Probus series likewise corresponds in strike with the beds of Manaccan, these lower Devonian strata having a general east and west trend, oblique to that of the underlying Lower Palæozoic strata. The fine-grained conglomerates of the Probus area were recognised from their lithological characters in 1902* as the equivalent of the Manaccan conglomerate. This likeness is borne out by microscopic examination, from which they are seen to contain a similar assemblage of rock fragments, resembling one another so closely as practically to preclude the possibility of their derivation from different sources, or from the same source at widely different periods. From these considerations it was at the same time recognised that it might represent an unconformity between the Silurian or older rocks and the Devonian rocks of Cornwall. The detailed investigation of the Manaccan district has proved the correctness of that interpretation.† The coarseness of the conglomerate in that area enables its constituents to be easily identified, and where it is closely associated with the Portscatho beds it is seen to be almost entirely composed of fragments derived from that series. The fact, moreover, that the boulders were veined with quartz prior to their incorporation in the conglomerate sufficiently indicates the magnitude of the break.

The Probus series follows a westerly course across the northern

* J. B. Hill. "Summary of Progress of the Geological Survey for 1902," p. 25.

† J. B. Hill. "Summary of Progress of the Geological Survey for 1905," and *Geol. Mag.*, 1906, pp. 206–216.

edge of the area to the coast at Porth Towan with an average width of a mile. Although no fossils have been found within this narrow strip, its northward extension in the adjoining map contains Lower Devonian fossils.

The sandy beds are frequently very tough and highly siliceous, and constitute good road metal. They are, moreover, often veined with calcite. Their common characteristic, however, is the thickness of the bands, which may sometimes attain to 20 feet, whereas the sandy beds of the Portscatho group seldom exceed a few feet in breadth, so that this feature, as well as the coarser texture and presence of lime, help to distinguish them. These grits contain pebbles of fine slate, sandy slate, fine impure grit or grauwacke, granular quartzite, sheared quartz, felsitic igneous rocks rich in felspar, and fine quartz-felsite, together with pyrites, tourmaline, muscovite, chlorite and limonite. The igneous pebbles sometimes include fluidal felspathic rocks, which Dr. Flett considers to be probably trachytes or orthophyres. Pebbles of felspar often occur in large numbers (3,870).* A specimen from a more quartzose type (3,871)* contains pebbles of quartz, orthoclase, oligoclase, felsite, and fine grit, lying in a fine quartzose matrix. There is less slate and fewer igneous fragments than in the preceding, but one or two small pieces of the characteristic igneous rocks are to be found, together with the sheared metamorphic quartzite.

The discontinuous nature of the coarser beds and the frequent paucity of rock sections has precluded its boundary being traced with accuracy; nevertheless, its east and west trend is sufficiently apparent, as a glance at the map will show; and in spite of the general absence of its coarser representatives, the group forms more elevated features than the Lower Palæozoic tract. At Porth Towan, where it reaches the coast, it is separated from the Portscatho group to the south by a fault. The latter group consists of sandy and argillaceous beds; while on the north side of the fault sandstones are rare, although some of the fine-grained sandy silts weather out into conspicuous bands from the argillaceous alternations. These beds are, moreover, slightly calcareous, and effervesce with cold hydrochloric acid, both as regards the normal rock and the small brown veins that ramify through it.

* These specimens were obtained from the area closely adjacent in Sheet 346.

CHAPTER VI.

IGNEOUS ROCKS.

I. Greenstone.

The greenstones that occur within this area are largely referable to the group of epidiorites. Taking Cornwall, however, as a whole, these rocks could not be conveniently classed with the latter, as many of them still retain original augite. It has been found convenient, therefore, to retain the older synonym, which is sufficiently wide to embrace the various petrological types that are nevertheless linked together by close ties of affinity.

The dominant minerals in these rocks are hornblende and felspar, while chlorite, biotite, epidote, iron ores, and quartz form the most important accessories; augite, garnet and axinite are in this area exceptionally present. They occur in elongated sill-like masses, some of which attain considerable size. As they have been involved in the earth movements that have affected this region, they have to a very large extent shared in the process of deformation to which the slates have been subjected. Moreover, their great development within the granite aureole of contact alteration has involved thermal metamorphism in addition. As the result of these changes they have often been profoundly modified, both as regards structure and mineral composition.

So far as this area is concerned, there is no good evidence that the group contains either lavas or tuffs. The coarser varieties are almost certainly intrusive, and the absence of well-defined ash beds points to the conclusion that the Palæozoic sediments of this part of Cornwall were unaccompanied by volcanic products. On the other hand, the decomposition of these greenstones and the adjacent killas obscures the junctions. Moreover, the mechanical deformation to which the rocks have been subjected still further masks their mutual relations; whilst, finally, the paucity of marginal sections is such that deductions based on such data are far from conclusive.

Although these rocks have a considerable petrological range, it is clear that most of them were originally dolerites or basalts, in which the primary augite has been replaced by hornblende. The researches of Messrs. Allport and Phillips* on the Cornish greenstones conclusively demonstrate this fact. While the more massive varieties of the rock have so far resisted dynamic metamorphism as to still preserve much of the original felspar, in others that mineral is recrystallised or profoundly altered. Moreover, considerable variation attends the relative proportions of the hornblende and felspar that form the principal constituents, while in the crushed varieties the secondary products may be so widely diffused as to efface the original character of the rock. The green-

* *Q.J.G.S.*, vol. xxxii., pp. 155 and 407, and vol. xxxiv., p. 471.

stones, however, are not confined to the basic types, but rocks of intermediate and possibly even of acid composition find their place within that group. That members of the andesitic family are present is certain, and it appears highly probable that trachytes are represented also.

For convenience, the greenstones will be described under four heads, according to districts, as follows :—Firstly, those in the granite aureole between Gwennap and Penryn. Secondly, those occurring to the east of Penryn, which are scattered over a broad tract west of the Carrick Roads, between Devoran and Falmouth, and lying mainly beyond the granite aureole. Thirdly, those between Camborne and Redruth that flank the smaller granite masses of Carn Brea and Carn Marth; and, lastly, the greenstone flanking the south-western margin of the Carnmenellis granite.

Area between Gwennap and Penryn.—From Bellevue to Ponsanooth there appears to be a continuous line of greenstone. After a break of about a mile and a quarter, it is again seen between Pengreep and Treviskey. That between Bellevue and Ponsanooth will be first described.

Bellevue and Ponsanooth.—Owing to the area being under cultivation and the infrequency with which the rock protrudes from the soil, the continuity of the sills cannot be demonstrated. At Bellevue a coarse-grained greenstone is seen, having apparently a width of about 80 yards. This rock is again visible at Lower Treluswell. Between that place and Burnthouse, where it has been quarried, it cannot be traced, but large blocks occur in a field between Treluswell and Burnthouse. Beyond the latter locality it has been quarried at Cosawes Pascoe. Another pit has been opened on this band about half a mile to the north-west, and this is the only quarry at present being worked. The seam appears to die out before reaching Ponsanooth. The coarse greenstone is accompanied by a smaller band of finer texture, which appears on its western side, in close proximity to it, at Lower Treluswell, Burnthouse, and on the main road near Ponsanooth, where a corresponding band also occurs on its eastern side.

The larger and coarser band is a massive amphibolite, resulting from the alteration of a coarse dolerite or gabbro. A specimen from near Bellevue (3,367) shows under the microscope large masses of fibrous hornblende, in a matrix of coarse felspar, in which a large number of the crystals are still idiomorphic, while many are broken and crushed. The rock is half a mile distant from the Carnmenellis granite, and it would appear that prior to contact metamorphism by the latter that it was decomposed, and while the original felspar remains, the decomposed pyroxene is replaced by actinolite. There is a sporadic appearance of actinolite amongst the felspars, probably due to a migration of the decomposition products. Iron ore is present in process of alteration to granular sphene, as well as fine needles of apatite, some of which are broken and may possibly be original. A specimen obtained from the new quarry near Cosawes Pascoe, and within 300 yards of the granite margin, is essentially the same rock, but under the microscope (3,371) is seen to be slightly sheared, and shows a

higher degree of granulitisation. It is a massive amphibolite, and the hornblende is more abundant than in the last rock, forming compact masses, very pale green towards their centres, mixed with a little pale brown biotite, the latter probably being a direct result of contact alteration. The felspar is partly in large plates, but occurs mainly in a fine granulitic condition, especially in the shear planes. Some magnetite and apatite are also present.

De la Beche* records that this greenstone is traversed at Burnthouse by an elvan. At present the quarries at that locality are no longer working, and, being densely overgrown, cannot be satisfactorily inspected. In one of the old greenstone pits on the north side of the inn a few elvan fragments are seen that correspond to the description given by De la Beche, but no trace of the rock *in situ* is now visible.

The finer-grained greenstone sill already referred to has been quarried at Lower Treluswell and at Burnthouse. A specimen selected from the latter locality, about 150 yards south of the inn (3,562), shows the rock to be decomposed and sheared. It is full of pale green fibrous hornblende, mostly divergent, and of felspar which is decomposed and sheared. The rock is almost in contact with the granite, and contains a few scales of biotite, probably due to contact metamorphism. The original structure of the rock, however, has been obliterated.

The fine-grained greenstone seen in a corresponding position to the amphibolite on the main road leading to Ponsanooth (one-eighth of a mile east of Cosawes) is little more than 100 yards from the granite margin. Fresher specimens are to be obtained than at Burnthouse, one of which (3,569) is seen under the microscope to consist of fibrous pale green matted hornblende; iron ores, surrounded by rims of sphene; felspars, partly simply twinned, partly untwinned, and partly polysynthetic. The latter are fractured, but in many cases their original outline can be detected. In other cases, however, (3,568) the felspar has been entirely decomposed to micaceous aggregates. Another specimen (3,567), which appears to belong to the same mass, shows the igneous rock to be brecciated and to contain veins of pyroxene and quartz, which may be ascribed to secondary alteration and the metamorphic action of the adjacent granite.

Pengreep and Treviskey.—This greenstone, like that of Ponsanooth and Bellevue, flanks the Carnmenellis granite, and its junction with the slate can only be approximately defined. It is about $1\frac{1}{3}$ miles in length, and its extreme breadth exceeds a third of a mile. It forms an irregular lenticle, the western portion of which contracts more rapidly than the eastern part. In the neighbourhood of Trebowland Vean it is only separated by about 70 yards from the granite. Notwithstanding its extent, the rock is of much finer texture than the mass extending from Bellevue to Ponsanooth. While portions are as coarse as in the latter, the greater part of the rock is of fine grain. Moreover, its texture is exceedingly variable, as may be seen within the compass of a limited

* "Report on the Geology of Cornwall," &c., p. 484.

section. This is well exhibited in the quarry at Devis (half mile S.S.W. of Gwennap) where patches, the crystalline nature of which is easily visible, succeed bands so fine in texture that the crystals can only be detected with a lens. Both types, moreover, alternate sharply with zones that are very finely sheared. The mass has evidently undergone considerable compression, the finer, more compact zones and those of coarser texture having been packed and squeezed together, and shearing set up along the latter type. The rock is partially mineralised with secondary pyritous products, while quartz veins apparently mixed with epidote cross the prevailing banding. Some of the finer cross veins are hornblendic.

Under the microscope all these bands are seen to be slightly schistose. Those most foliated consist of fibrous green actinolitic hornblende, arranged to form irregular wavy folia; the crystals are small and in some bands are densely matted, while in others they are scattered through a ground mass of felspar which is finely granular and shows no crystalline form. Epidote is common in very minute grains, and there are comparatively large masses of iron oxides and pyrites (3,443).

The two less schistose bands are rocks of essentially the same type, but contain in addition some fine scaly deep brown biotite, which in all probability indicates contact alteration.

The eastern portion of the mass near Pengreep is partly of coarser texture, a specimen of which (3,368) bears a strong resemblance to the rock described from Bellevue (3,367). It consists of large crystals of fibrous hornblende, while the felspar is partly idiomorphic and partly granulitic, and the section shows foliation planes. The iron ores in this rock are well preserved. A finer-grained rock from the same locality resembles the greenstone of Devis Quarry. It shows no sign of crushing beyond traces of shear planes like those in the last specimen. The felspar is much weathered, and there is a little brown biotite. This greenstone is pierced at Burncoose by an elvan dyke. It is seen in a quarry amid the adjacent killas, but it is not now visible within the greenstone zone itself, where the land is under cultivation. De la Beche, however, states that it traverses that rock.*

A small mass of greenstone occurs beyond the main band about a mile to the north-east of Burncoose. Its limits, however, cannot be precisely defined, as its presence is only detected by the débris turned up in the soil. In the larger mass quarries have been opened, the principal of which are at Devis and near Gear.

AREA EAST OF PENRYN.—The greenstones of this district occur in a zone from Restronguet Creek on the north to the neighbourhood of Falmouth on the south, and are most strongly developed in Penryn Creek, where they are seen both on the Flushing and the Falmouth shores. They occupy smaller bands than most of those already described, are usually highly decomposed, but appear to be less sheared and are marked by a more acid composition.

* Report previously cited, p. 186.

The most extensive of these masses is seen at Flushing, at the entrance of Penryn Creek, where it has a breadth of about 200 yards; it ascends the hill for about 350 yards and then disappears. The rock has been extensively quarried, and formerly a silver lead lode was worked along its eastern margin at Wheal Clinton. It occurs at the extreme limits of the metamorphic aureole, and its easterly margins have a knotted appearance. Apart from this, the rock does not appear to have suffered from contact alteration. It is usually much decomposed, with an occasional tendency to a foliated arrangement. The colour is pale green and the texture is fine, but can be resolved by the naked eye into an admixture of felspar and a green chloritic mineral. Under the microscope (3,373) it is seen to be largely made up of felspar, very little granulitised, but consisting mainly of large and often idiomorphic individuals, though frequently broken. The hornblende has all decomposed to chlorite, and the iron ores are weathering to leucoxene. The rock is a somewhat basic andesite that has suffered but little from cataclastic movements.

The rock is not visible on the Falmouth shore,* but two outcrops that occur along the same line on the east and south of Penwerris appear to be identical with it in composition. The former has been quarried along a band of white quartz about 8 yards wide, while the latter can only be detected by the detritus among the soil. Where the texture is finest it appears to have been cleaved.

The following analyses of these rocks were made by Mr. J. H. Collins.† The first refers to the rock at Flushing, and the second to that east of Penwerris from Beacon Hill:—

	I.	II.
SiO_2	55·45	53·30
Al_2O_3	25·95	24·48
Fe_2O_3 } FeO	6·07	12·02
CaO	1·26	0·73
MgO	2·39	3·75
K_2O	1·48	trace
Na_2O	4·30	1·27
H_2O	2·85	4·70
	99·75	100·25
Sp. Gr.	2·66	2·72

* It was apparently noticed, however, both by Mr. Collins, and later by Mr. F. J. Stephens on the Falmouth shore south of Green Bank Pier. *Trs. R.G.S. Corn.*, 1896, vol. xii., part ii., p. 51.

† *Journ. Roy. Inst. Corn.*, vol. viii., p. 202. In that publication Mr. Collins has included these greenstones with the mica traps. See paper on the plutonic and other intrusive rocks of West Cornwall by J. B. Hill. *Trs. R.G.S. Corn.*, vol. xii., p. 7., 1901. Mr. F. J. Stephens noted its difference from the normal mica traps of the district in a paper on the greenstones of Penryn Creek in 1896, one of which he considered to be an altered ash bed. *Trs. R. G. S. Corn.*, vol. xii., part ii., p. 49.

On the south side of Penryn Creek, below Penwerris Church, two greenstones are seen about 55 yards apart. The easterly mass has a width of about 80 yards, but the whole breadth of outcrop is not visible. At its eastern margin the rock is most massive, enclosing harder and fresher cores. It is grey in colour, and vesicular, and even in the finer and less massive portions tiny felspars project on the weathered surface. The rock is much decomposed, even where most solid, and the boundary with the slate is not seen. The westerly mass is exposed for about 12 to 14 yards, but it may be larger. It is more decomposed and never solid, but tiny felspars can be detected on the weathered surface. Above high-water mark it is brown and friable. The bed contains similar vesicles, notwithstanding that it is more cleaved than the band to the east. Under the microscope a specimen from the latter and more solid mass (3,565) is seen to be a much decomposed, and practically unsheared, porphyritic and vesicular igneous rock which apparently belongs to the trachyte group. It contains abundant phenocrysts of idiomorphic felspar, some of which are untwinned, but most are simply twinned on the Carlsbad plan ; a few are plagioclase. These lie in a ground mass composed of small felspar crystals, and filled with small scales of secondary mica and chlorite, so that the original structures can no longer be deciphered. The abundant steam cavities are filled with granular quartz, mica, and chlorite. So far as the micro-section shows, this rock is practically unsheared, the porphyritic felspars are unbroken, and the vesicles retain their original irregular shape, but the hand specimen indicates that it has been subjected to a certain amount of deformation.

These bands appear also on the northern shore of the creek west of Flushing, where they are only about 15 yards apart. Here they are much disturbed by interfolding with the slates, and by small faults and thrusts that are often so closely arranged that the truncated cores are reduced to the thickness of a foot.

At Mongleath, about a mile to the west of Falmouth Parish Church, a highly decomposed greenstone has been quarried that is probably allied to the rocks last described. It is a lilac grey fine-grained rock in which small felspars are seen in the more solid portions. The boundary with the slate is not seen. Under the microscope (3,564) it is so much altered and decomposed as to entirely lose its original character. It consists principally of a turbid felspar in very irregular grains, decomposed and obscured by abundant enclosures of biotite, chlorite, and iron ores. These felspars are mostly untwinned, sometimes simply twinned, rarely polysynthetic. They are never idiomorphic, but form masses of extremely irregular shape. The other minerals form small specks or tiny flakes. Biotite is the most common ; it is usually irregularly scattered, but is in some parts arranged along definite curving lines. Irregular black patches of iron ore are frequent, and there is a good deal of disseminated chlorite. There is here and there a very small quantity of quartz, and diffused ferruginous stains are conspicuous in places. Dr. Flett is of opinion that the rock is undoubtedly igneous, that it is both decomposed and

sheared, and belongs, in consequence, to the greenstone group. It is exceptional in the absence of hornblende, the abundance of felspar, and the general resemblance it presents to the paler felspathic andesites. It may even approach the trachytes, but without detailed chemical analysis its affinities cannot be determined.

To revert to the sections along Penryn Creek, a small greenstone mass occurs on the southern shore near Boyers Cellars. It is a grey massive band, fine grained, cleaved, and much decomposed. It varies in width from 6 feet upwards. The ground is so disturbed by small fractures as to obscure its relations to the slate. It weathers with a yellowish brown crust, and fresh portions are difficult to obtain. It appears to be very felspathic, and is probably related to the greenstones of Penwerris and Flushing already described. This rock has been considered as a volcanic ash* but there does not appear to be good grounds for separating it from the bands just referred to farther east, the igneous origin of which is clear.

Between Penryn Creek and Restronguet Creek a few greenstones are met with. They can seldom, however, be traced for any distance, and are usually highly decomposed, and in most cases seem to be allied to the andesitic greenstone of Flushing. At Carclew one of these bands is sufficiently fresh for microscopic examination (3,563). It contains large patches of chlorite, mixed with granular felspar, a little quartz, and iron ores in large grains. Hornblende is less common, having usually weathered to chlorite. The rock is both decomposed and sheared.

A band appears to extend from Sailor's Creek to Woodlands where it has been quarried, both at the latter locality and near Trevissome Farm. On the south side of Restronguet Creek, about one-third of a mile north-west of the quay, there are three exposures of decomposing greenstone, one of which is 30 yards broad. These, like the band last described, have suffered but slight deformation from mechanical stress, and resemble the andesitic greenstone of Flushing. A similar rock is met with on the shore of Carrick Roads, below Great Wood, only 4 or 5 feet in width, in which shearing has proceeded further. The greenstone coloured on the old map to the east of Trevissome Farm was not seen in our survey, but Mr. Collins confirms its existence at that locality.†

CAMBORNE AND REDRUTH DISTRICT.—The greenstones of this area are distinguished by a basic composition, a fine-grained texture, a more or less uniform shearing, and the presence of veins that are frequently strongly garnetiferous. A broad band extends south-westerly from Camborne to the margin of the map. In a north-easterly direction, from Camborne to Treleigh, the band is apparently discontinuous. It is, moreover, found in isolated bodies in the mine workings of this area, as at South Roskear, East Pool, and many other localities. The boundaries

* F. J. Stephens. *Trans. Roy. Geol. Soc. Corn.*, 1897.

† *Journ. Roy. Inst. Corn.*, vol. viii., p. 194. Mr. Collins, however, has included this band amongst his mica traps.

of this greenstone can only be approximately drawn as sections and surface exposures are few. An excellent section, however, is afforded by the railway cutting west of Camborne Station, where an elvan is seen to traverse it. Two smaller patches of greenstone are dissected by the railway cutting between Camborne and Pengegon Coombe. It has also been quarried in the neighbourhood of Tuckingmill. In other localities reliance has to be placed on the rock fragments of the soil and on local information. As this stone has been extensively utilised for the building of hedges and other purposes, and as the blocks employed are often of enormous size, great difficulty is experienced in discriminating the nature of the country rock where sections are scarce, greenstone débris often predominating where slate constitutes the bedrock.

The railway cutting between the goods shed at Camborne Station and the bridge near Osborne House affords a continuous section of the garnetiferous greenstone for a length of one-third of a mile, and exposes its junction with the slates. The greenstone is of exceedingly fine texture, and is usually very closely banded. It is seldom massive, but is generally rudely fissile and decomposing, with a tendency to cleavage somewhat like the slates. It frequently weathers to an ochreous crust, and is often friable and soft. The rock is not only characterised by an absence of vein quartz, but by the presence of abundant veins of brown garnet. The veins are often two or three inches in thickness, and are at times so closely packed as to occupy half the mass of the rock. They are usually, however, much thinner, and are often represented by mere cores, some of which are of small size. They are parallel to the banding of the rock, in the crumpling of which they share. They are not confined, however, to these planes, which they frequently transgress, and often coalesce. The garnetiferous veining is bounded by a very pale greenish margin, contrasting strongly with the darker green matrix of the rock. Moreover, veins of this nature are common in which the garnet is absent. This mineral occurs both in a massive condition and in well-defined crystals, while the veins frequently decompose into ochreous material. The junction with the slate is seen at both ends of the section, but the disturbances which have affected both rocks do not admit of its precise nature being determined. Under the microscope (3,919) the greenstone is seen to consist of small green hornblendes, arranged in strings and bundles in a matrix of clear granular felspar, so fine grained as to form in some places almost a crypto-crystalline mosaic. Besides grains of iron oxide occasionally converted into sphene, clear brown biotite and chlorite are present, but no garnet.

At Weeth Farm, at the spoil heap of Gustavus Mine, a specimen of greenstone of the same general type was veined with green hornblende, quartz, and greenish pyroxene (3,920). Another fragment in a field from the same locality (3,921) is a fine-grained greenstone traversed by one of the pale green veins formerly alluded to, the latter consisting of

granular pale green or colourless pyroxene, mixed with micaceous products after felspar. Epidote is rare or absent in the vein, and there is no garnet, but it is cut by another which is filled with colourless fibrous highly-polarising minerals, probably of the zeolite group. In a quarry near Tuckingmill Gasworks a garnetiferous patch in the greenstone (3,922) consists of pink isotropic garnet, sometimes zonal, frequently intergrown with epidote, and never distinctly idiomorphic, but often in skeleton crystals. It is mixed with pale green pyroxene, colourless epidote, chlorite, granular and crystalline sphene, and colourless micaceous patches which are secondary after plagioclase felspar. Hornblende occurs in the greenstone, but very seldom in the vein. Calcite, although not visible in the slide, occurs in the hand specimen in large patches. There are some fairly large crystals of pyrites and a few scales of chlorite.

The greenstone met with in North Pool Mine, presumably from the Daubuz lode, has been brought to the surface at Broad Lane. A specimen shows the rock to be full of parallel bands or veins of the pale green material in which garnets are interspersed. Under the microscope (3,923) it is seen to consist of fibrous hornblende, epidote, weathered felspar, and chlorite, with pyrites, a few grains of garnet, sphene, a small quantity of carbonates, and occasional traces of pyroxene, but epidote and felspar are the principal constituents. The epidote is pale greenish yellow, and very similar to the pyroxene, though not so green in colour. The hornblende may be partly secondary after pyroxene. The weathered felspar is nearly always untwinned, and may be an orthoclase. The garnet is more conspicuous in the hand specimen than in the slide. The veins in this rock, therefore, are largely made up of epidote with garnet subordinate, which an inspection of the burrow débris suggests.

The greenstone exposed in the railway cutting about half a mile north-east of Camborne Station is of the same type, although generally much weathered, but the veins are characterised by an absence of augite. One specimen (3,924) is a sheared greenstone, with finely fibrous or prismatic hornblende disseminated in a matrix of granulitic felspar with iron ores and minute grains of sphene. Small scales of brown biotite are mixed with the hornblende. A vein of hornblende traverses the section, but this contains no garnet, pyroxene, or epidote. Another specimen (3,925) is a similar rock, but coarser in grain, in which the hornblende is compact instead of fibrous, and the slide contains a little pale epidote, augite, and sphene. Another part of this mass is a compact fine-grained sheared greenstone, but without veining. This rock (3,926) is conspicuous for the abundance of the secondary augite in its matrix. It occurs as a clear pale green pyroxene in crystals up to a millimetre in diameter, occasionally showing crystalline outline, though as a rule not displaying distinctive form. They contain a few enclosures of granular sphene or felspar, and sometimes of clear green hornblende in small compact crystals, but occasionally fibrous and radiate. These all lie in a matrix of

minute felspars, forming a mosaic of small grains mixed with granular sphene. Epidote is scarce, although a thin vein of this mineral traverses the section, but no garnet is observed. The matrix of the rock is very like that of some of the sheared greenstones, but the large pyroxenes have evidently developed after the shearing was complete, and may be ascribed to the contact action of the adjacent granite, two fine-grained sills of which are seen in the railway cutting to pierce the greenstone.

The south-westward extension of the Camborne mass was traced by Mr. Dixon to the edge of the map and into the adjoining sheet (351). In the latter area the rock is sometimes both uncrushed and unweathered, and constitutes an ophitic diabase, the structure of which often approaches that of a gabbro, so that its intrusive nature may be confidently accepted. To the south of Polstrong, although not deformed, it has experienced mineral reconstruction, hornblende having replaced augite, and the twinning planes of the felspar are obliterated (3,787). On the other hand, according to Mr. Dixon, "spotting" has been confined to sheared zones. A specimen of this nature from the railway cutting west of Penponds Viaduct consists mainly of pulverised felspar, containing parallel streaks of magnetite and leucoxene, together with spots of sub-radial hornblende, epidote, and chlorite, of square or rhomboidal shape, whose absence of distortion points to their production subsequent to the deformation of the rock (3,785). Another example of "spotting" in which the felspathic constituents have been modified is afforded by the sheared greenstone exposed in a quarry to the north-east of the latter locality (3,784). The crag lying to the south of the same viaduct, on the eastern side of the valley, is formed of sheared greenstone in which the felspar has retained its original structure. Other greenstone outcrops occur at Penhale and south of Trevoole, while a rock resembling this type was noted by Mr. Dixon near Watergate (Illogan), at a considerable distance from the nearest greenstone horizon (3,646).

These peculiar intrusions, therefore, of the Camborne district are characterised by secondary veins infilled with garnet, epidote, augite, hornblende, felspar, and quartz, either singly or in combination. Not only are these secondary minerals disposed in veins, but, with the exception of garnet, occur diffused in the matrix of the rock in the same manner as the secondary biotite. These rocks lie within the aureole of contact metamorphism of the granite, and the presence of those secondary minerals may be confidently attributed to such contact action. It may be noted, however, that where they are in closest proximity to the granite the garnet appears to be absent. Mr. J. A. Phillips* thought it probable that they also contained axinite, and considered them to represent volcanic ash beds. While their fineness of texture might well lead to the supposition that they were the metamorphosed products of volcanic muds, their matrix frequently

* On the so-called greenstones of Western Cornwall. *Q.J.G.S.*, vol. xxxii., 1876

closely resembles that of the normal sheared greenstones, the igneous origin of which is undoubted, and their passage into coarse types that represent gabbros points unmistakably to their intrusive origin. There is an entire absence, moreover, of clastic structure, and in this connection it may also be remarked that the presence of undoubted ash beds, or even lavas, has not been demonstrated in this part of Cornwall.

The following analysis in duplicate of a garnetiferous greenstone from Carn Camborne is taken from the paper of J. A. Phillips, already cited:—

Water { hygrometric	·14	·12
Water { combined	·60	·65
Silica	48·30	48·41
Phosphoric anhydride	trace	trace
Alumina	17·04	17·02
Ferric oxide	2·73	2·68
„ persulphide	traces	traces
Ferrous oxide	9·50	941
Manganous oxide	trace	trace
Lime	13·30	13·15
Magnesia	6·18	6·20
Potassa	·30	·30
Soda	2·01	2·13
	100·10	100·07

Specific gravity = 3·03.

As pointed out by Mr. Phillips, the composition of this rock closely resembles that of the metamorphosed dolerites in the Penzance district. Moreover, the only rocks in the latter area that were regarded by De la Beche as highly altered ash beds differ widely in chemical composition from the rocks at present under consideration.

To the east of Pendarves House, and also at Treslothan, two bands of greenstone occur that belong to the class just described. Their exposures, however, are scanty, and their boundaries have been taken from the old map. In Rosewarne Park and in the north-east of Camborne there are two greenstone exposures, each of which is traversed by an elvan dyke. In other localities, as at Higher Rosewarne, North Pool, and Broad Lane, where these greenstone bands have been drawn on the map, there are no surface indications, but the position of their outcrops has been approximately drawn by Mr. MacAlister from information afforded by mine plans.

The band that is quarried at Tuckingmill* is of coarse texture and is a fine-grained dark green sheared greenstone in which the characteristic veining of the garnetiferous type is absent. The quarry is extensive, so that the rock can be satisfactorily examined. Under the microscope (3,914) it is seen to consist of

* 730 yards north by west of All Saints' Church.

fibrous subradiate green hornblende, forming irregular bundles and tufted growths, mixed with granulitic felspar, iron oxides, apatite, and a little brown biotite. The felspar forms a mosaic of very small grains, which resembles the ground mass of a felsite.

South-Western District.—An exposure of greenstone situated in the south-western corner of the sheet, at Wheal Trannack, in the Cober Valley, and in close proximity to the margin of the Carnmenellis granite, may be referred to here. This mass is exposed on the hillside forming the eastern banks of the stream, where it has been quarried; the eastern tongue of the lenticle is seen in the railway cutting above, where it has been pierced by a fine-grained granite. To the west of the Cober River the greenstone is at present being quarried. It is a compact rock of normal type, like that already described from near Tuckingmill, but contains much more biotite, due to the close proximity of the granite, this mineral being the only ingredient due to contact action. A specimen from the railway cutting (3,953) at the thin end of the lenticle shows acicular green hornblende, forming divergent aggregates in a matrix of finely granulitic felspar, scattered masses of iron ores surrounded by borders of sphene, and a few small crystals of apatite and pyrites. A specimen from the quarry on the left bank of the stream from the interior of the rock is coarser in grain, dark green in colour, and with bronzy areas, owing to the development of numerous fine scales of brown biotite. Under the microscope (3,916) it is massive, not schistose, with much pale, clear green amphibole that forms large compact masses with very irregular borders, and, consequently, differs from the aggregates of fine hornblende needles which are usual in the greenstones. This hornblende has only a very slight pleochroism and is generally perfectly fresh. A clear matrix of fine granular felspar surrounds the hornblende, forming a mosaic of irregular, usually untwinned grains, with occasionally larger individuals, which, however, are never idiomorphic. The biotite is of a dark chestnut brown colour, and occurs in small scales, usually grouped together to form patches of irregular shape, either in the felspar or scattered through the hornblende. Small prisms of hornblende and scales of biotite lie in the felspathic matrix. There is also a little apatite and iron ores, the latter sometimes surrounded by borders of sphene. The abundance of biotite, the compact nature of the hornblende, and the coarseness of the felspar mosaic, all indicate that this rock has been subjected to contact metamorphism.

II. Granite.

The principal granite mass within this sheet is that of Carnmenellis, which forms a rudely circular boss extending from Buller Downs, about one mile south of Redruth, on the north, to slightly beyond the southern edge of the map. On the east it extends to Budock and Penryn, while its western margin reaches from the vicinity of Nancegollan Station to the westward of Crowan and Garnick. To the north of the Carnmenellis

boss lie the two adjacent masses of Carn Brea and Carn Marth. Subordinate intrusions flank the Carnmenellis granite near Treluswell and Budock on the east, and on the south-western margin from the vicinity of Crowan to the valley of the Cober. On the north side of the Carn Brea granite a small sill of aplite or fine-grained granite traverses a greenstone in the railway cutting near Pengegon.

CARNMENELLIS GRANITE.—The Carnmenellis mass is essentially a muscovite-biotite granite, of acid composition, in which tourmaline is a common constituent, while andalusite is frequently present. Apatite and zircon sometimes occur, while topaz and pinite are rare. The granite has often undergone great modification, especially in the vicinity of the mineral lodes, and in these cases new minerals have been introduced. The rock is frequently porphyritic by the dispersion of large idiomorphic felspars of orthoclase and plagioclase in a finer-grained base. Such felspars often exceed an inch and, exceptionally, two or three inches in length, but seldom attain the abnormal dimensions that characterise the granites of the Land's End and St. Austell. The texture is, nevertheless, coarse as compared with British granites generally.

This rock, while fairly uniform throughout, nevertheless exhibits local deviation, both as regards composition and coarseness. Speaking generally, the eastern margin is not only of finer texture, but is perceptibly richer in biotite. These characteristics mark also a greater part of the southern margin. On the south-west and west, however, there is no perceptible difference as regards texture, but it continues to be rich in biotite, almost to the entire exclusion of white mica. It is sometimes veined with pegmatite, especially in the vicinity of Ponsanooth. Contemporaneous veins of fine-grained granite or aplite are common over the mass. They are less abundant, however, in the eastern portion, but are extremely numerous in the central district, while in the west two areas of fine-grained granite occupy tracts sufficiently extensive to be separated on the map. One of these, exceeding a square mile, occurs between Bolitho and Boswyn, the other forms a protruding lobe, comprising a quarter of a square mile, on the margin of the granite at Praze. The latter is a a fine-grained biotite-tourmaline-granite occurring amongst coarse granite of similar composition, to which its marginal relations are obscure. The mass between Bolitho and Boswyn yields more exposures. Over a large part of its area the fine texture is fairly uniform, often approaching that of an elvan, but veins of coarser granite are of frequent occurrence, while at times the finer type itself may contain idiomorphic felspars an inch in size. The marginal relations are usually obscure, but occasionally the fine granite sends veins into the coarser normal rock. At Crowan Beacon, however, the passage of the normal granite into the fine-grained type is seen. Here the former gives rise to tors with rudely stratiform structure which are absent in the area occupied by the latter. It passes first into a coarsely porphyritic granite, the porphyritic constituents being identical with the individual

crystals of the normal rock, but lying in a ground mass of finer material. The porphyritic individuals, however, both felspar and quartz, are idiomorphic, so that with a sufficiently fine matrix we reach a rock indistinguishable from some of the elvans.

Structures.—The system of jointing pertaining to the Carnmenellis granite bears a definite relation to the crystalline arrangement. There are three well-defined joint planes: one set of vertical joints, having a prevalent direction of north-north-west, is crossed by another vertical set at right angles. These two systems, in conjunction with a third set more or less horizontal, divide the whole rock into a set of rough prismatic segments. The regularity of these joint planes has been an important factor in the development of the granite industry of Cornwall. The planes which trend north-north-west are termed "cleaving-way" joints, those at right angles are the "tough-way" joints, while the horizontal planes are known as "floors" or "quartering-way" joints. The grain of the rock has been found to correspond with the position of the joints, hence their names.

The "tough-way" joints, or those which approximate to an east-north-east direction, may sometimes be faults; instances being common where the horizontal "floors" have been thrown by them as much as 2 feet, or where the joints display slickensided surfaces, indicative of relative displacement of the walls. Further, the fine-grained granite and aplite veins tend to take a course parallel to these same joints, while the elvan dykes undoubtedly follow the same parallelism.

The horizontal joints or "floors" producing stratiform weathering are characteristic features in the field. De la Beche* considered them as original structures, and the fact of their being faulted by the "tough-way" joints proves them to be older than the movements along those divisional planes. Later joints, however, occur which cannot always be distinguished from the true "floors," into which they appear to merge. The intervals between these horizontal joints or "floors" increase with depth from the surface. In Pelastine quarry the joints are 60 feet apart, while in Polkanuggo† quarry the disposition of the joint planes would admit of blocks being raised 120 feet long, 28 feet wide, and 30 feet deep.

The rock cleaves most readily along planes parallel to the "floors" or horizontal joints. The next easiest cleaving plane is that parallel to the "cleaving-way" joints, while the rock cleaves most irregularly parallel to the "tough-way" joints. An examination of numerous sections in which this triple jointing is visible appears to show a distinct tendency to orientation along planes parallel to the horizontal "floors," and to the "cleaving-way" joints, although no absolute regularity in this respect has

* Report (previously cited), p. 163. This structure was also noted by Dr. Boase.—"Treatise on Primary Geology," 1834, p. 96.

† The quarries are thus designated by Messrs. John Freeman & Co., by whom they are worked.

been observed. While in many instances these planes depart from the normal direction, it is unusual to find more than one joint system deflected in the same exposure. The greatest irregularities in the jointing and corresponding cleavage occur in the vicinity of the granite veins. The horizontal joints, although often undulating, are the most regular of all. The cleaving planes of the rock are not always strictly parallel to the joints, yet, on the whole, the parallelism between the joints and the directions along which the rock most readily splits is unmistakable. From the evidence of a large number of sections there is reason to conclude that not only is there a close connection between the major joints and the grain of the rock, but that this grain is dependent on the mineral arrangement of the granite, and that all three phenomena are closely related. The crystalline structure appears to consist, first, in a tendency for the mica to lie with its basal planes horizontal; secondly, in a disposition of the felspars, both as constituents of the matrix and as porphyritic individuals, to rest with their flat sides in a similar position; and, thirdly, in the orientation of the felspars with their long axes parallel to the "cleaving-way" joints. The first and second of these structures probably explain the proneness to cleave parallel to the horizontal joints, while the third seems to show why the rock tends to cleave in planes parallel to the "cleaving-way" joints. The rock does not differ outwardly in any marked degree from ordinary granite; yet it has evidently undergone a rude and initial stage of foliation, whereby its component minerals have been forced to rearrange themselves in a definite direction so as to acquire a cleavage.

The set of major joints, which trends approximately east-north-east, corresponds to an extensive system of fissures that has been formed in the granites and Palæozoic rocks of Cornwall by the subterranean disturbances, to which the former owe their origin and the latter their deformation. This system of fracture is parallel with the axis of granitic intrusion, and also with the general trend of the elvan dykes and mineral lodes, both of which have occupied its fissures.

These phenomena are well illustrated in the Carnmenellis mass. Within that granite, in the Mabe and Constantine districts, mineral lodes and elvan dykes are practically absent, while the east-north-east system of fissuring is almost entirely confined to the visible joints. In the parish of Wendron, which forms the central belt of that granite, this system of fissuring has been so sensibly increased that the stone, which is raised on a large scale in the two former parishes, can seldom be profitably wrought. With this change elvan dykes make their appearance, likewise an extremely attenuated set of mineral veins that have been worked for tin; moreover, the granite, which is of coarse texture, is extensively veined by finer-grained material. The east-north-east fissuring is no longer confined to the major joints, but the interspaces between them are very closely fractured along parallel planes. Frequently they consist of tiny cracks that sever the various crystals along their course. In the next stage, the cracks have been infilled with quartz, which has been followed by the in-

troduction of schorl as an accompaniment of that mineral, and finally to almost its total exclusion. With the oncoming of wider veins the rock takes on a banded appearance, the black schorlaceous seams standing out in striking contrast to the granite. The schorlaceous veins carry tin, and in some instances it is quite clear that the lode coincides with the east-north-east joint. Over the whole district the schorlaceous bands rarely exceed a few inches in width.

When this granite is followed, however, further north, towards the marginal zone, the extent of the elvans and the magnitude of both fissure and lode have reached their maximum.

Microscopical Character.—Having given a general description of this granite, it will be convenient, before touching on local characteristics, to present a brief relation of its microscopic characters.

A fairly typical specimen of the coarser granite representing the interior of the mass was taken from Eathorne, in the parish of Mabe. As a whole the rock is very fresh, and is a muscovite-biotite-granite with accessory tourmaline and andalusite. The felspar is mainly perthitic orthoclase, but there is also some microcline and plagioclase. The biotite is rich brown, with strong pleochroic halos. Muscovite is common, and often occurs in parallel growth with biotite. Numerous small grains and prisms of andalusite lie scattered through the section. They are sometimes nearly colourless, but others exhibit marked pleochroism, which ranges from rose pink to colourless. There are one or two irregular grains of deep brown tourmaline, and apatite is common in unusually large crystals. Zircon is present in considerable quantity, especially in the biotite. The quartz contains numerous large fluid cavities with mobile bubbles. In parts of the section the felspar is decomposed, and the biotite has passed into chlorite (3,556).

To the north of the latter locality, in the vicinity of Longdowns, a specimen was obtained at the junction of the normal granite with one of the finer-grained veins. Here the coarse rock is a biotite granite containing andalusite, while the finer-grained vein is a tourmaline granite (3,356).

At Chywoon the fine-grained granite that occurs amongst the coarser and more normal type is a tourmaline-muscovite-granite (3,357). On the other hand, a fine-grained granite from Trevales is a muscovite-biotite-granite containing both andalusite and tourmaline. The felspar is largely perthitic orthoclase, but there is also an early generation of well-crystallised plagioclase. The biotite is deep brown, with strong halos. Muscovite is abundant, and andalusite occurs in small grains with characteristic pleochroism. There are a few small grains of brown tourmaline, and apatite is common (3,557).

The preceding specimens, taken from the eastern region of the granite, represent its normal condition in an area free from brecciation and mineral veins.

It has been mentioned that two fairly large tracts of fine-grained granite have been mapped in the west, in the parish of

Crowan. A specimen from the more westerly mass, and near the granite margin from Trethannas, shows a fine-grained tourmaline granite with a little chlorite after biotite, and much muscovite. Perthitic orthoclase occurs in small porphyritic crystals (3,933).

The corresponding granite extending from Bolitho to Boswyn shows a passage to quartz porphyry, and the quartz is often idiomorphic. A specimen from Crowan Beacon may be described as a fine-grained porphyritic muscovite-biotite-granite with topaz. Both quartz and felspar occur as porphyritic constituents. The biotite is clear brown and weathering to chlorite. Topaz is fairly common, but never idiomorphic. Muscovite is less frequent than usual. The ground mass is micro-granitic, and in places somewhat poikilitic. Tourmaline is rare and occurs only in one or two small crystals (3,853). A specimen from the northern part of the mass, obtained from a locality a quarter of a mile south-east of Croft Michell, is really a quartz porphyry with porphyritic quartz and turbid felspars. These are often surrounded by coarsely graphic halos, but the main part of the ground-mass is micro-granitic. Chlorite is common, probably after biotite. Muscovite is mainly secondary in the felspars. There are many large rough apatites, but only a few grains of tourmaline are visible. Dr. Flett observes that the amount of micro-pegmatite in this rock is exceptionally large for a Cornish granite (3,851).

A sample from the same locality, but in which mineral alteration and silicification is developing, is a porphyritic granite, with muscovite, tourmaline, and biotite. The biotite is weathering into chlorite with strong black pleochroic halos. The tourmaline is in small ill-shaped prisms and always of a brown colour. Apatite is common. Muscovite is both primary and secondary. There is not much evidence of secondary quartz-tourmaline infiltration, although some of the felspars of the ground mass have been partly replaced by quartz and muscovite; the porphyritic crystals, however, are unaffected (3,852).

Besides the normal condition of the granite, in which the original mineral constitution is still intact save for a few unimportant decomposition products, there are large areas in the parish of Wendron and on the western border where planes of fracture closely traverse the granite, and in which infiltration of quartz and tourmaline has modified the character of the rock. The bands and veins of quartz and tourmaline have already been alluded to, but in addition to these secondary veins the granite itself has been converted into greisen, and the various stages of alteration can be followed from the unaltered granite into a normal greisen. Sometimes this complete change has been effected within the limits of a few inches. The veins have frequently been subjected to movement and breccias produced; moreover, by the introduction of stanniferous material into the latter, we reach the stage of a mineral vein. The lateral transition from such mineral veins into normal granite can be favourably studied in the district of Wendron. Besides the decomposition of the felspar and its replacement by quartz and schorl, the biotite has been converted into chlorite; the tourmaline, which in the normal

granite is usually brown, is often either entirely blue or edged by blue borders. The succeeding examples will illustrate the processes of alteration.

The following specimen (3,850), taken from East Wheal Lovell, about half a mile east by north of Hendra, represents a fine-grained granite which passes gradually into the coarse normal type. The fine granite becomes progressively studded with porphyritic felspar crystals until finally the matrix is insignificant and the felspars exceed a square inch in size. The fine-grained specimen is a muscovite-tourmaline-granite without biotite. The felspar is orthoclase with a small amount of plagioclase. The tourmaline occurs in irregular zonal brown prisms, sometimes edged with blue, and often with blue pleochroic halos, but never fibrous and rarely idiomorphic. Muscovite is common in large idiomorphic tablets, and also as small secondary scales in the felspars. Large irregular apatites are numerous, and the quartz is full of fluid cavities.

The next specimen (3,854), from a locality three-quarters of a mile north-east of Hendra, is a granite which, although showing mineralisation in the field, yet in the slide only exhibits the earliest changes in the form of conversion of the felspars into micaceous aggregates. It is a muscovite-biotite-granite with tourmaline. The rock is fairly coarse in grain, and shows pink felspars, which, at a distance of rather more than an inch from the joint face are fairly fresh and have their characteristic twinning and micro-structure, but nearer the joint become dark grey and are changed into aggregates of pale shimmering mica. Silicification is not conspicuous. Muscovite and biotite are both present in well-formed crystals. The latter is decomposing into dark green chlorite. Brown tourmaline occurs in scattered grains and in spongy masses which prove to be in graphic intergrowth with quartz. It is only rarely blue upon its edges.

In the next rock (3,864), from Medlyn Moor Mine, the granite is passing laterally into a quartzose modification or schorlaceous greisen. In the granite there is a little brown schorl and much muscovite, chlorite probably after biotite, and large crystals of perthitic orthoclase. In the greisen quartz preponderates, the brown tourmaline has well-marked blue borders, the felspar has disappeared, and its place is taken by aggregates of quartz, fine muscovite, green chlorite in small subradiate scales, and occasional needles of pale blue tourmaline. The original muscovite, in large stout crystals, remains unchanged. The slide shows the various stages of alteration of the felspar, which can be clearly followed in a distance of less than a quarter of an inch measured at right angles to the surface of the fissure.

In another specimen from the same locality (3,855) the felspar has practically entirely disappeared, having been replaced by quartz and muscovite. There are a few prisms of tourmaline, brown in their centres and blue on their surfaces. Apatite and chlorite are also present. This is a granite that has been converted into greisen.

The granite is often traversed, as already described, by quartz-

tourmaline veins. A specimen was sliced from Rame Common (3,856). In the vein the quartz is granular, and the tourmaline is blue and prismatic. The granite is rich in muscovite and in chlorite after biotite, some of this chlorite being vermicular. Tourmaline is found in the granite in large brown crystals edged with blue, and apatite is rather common. The felspar is much altered and rarely shows its characteristic micro-structure, being largely converted into muscovite, quartz, and kaolin.

A quartz-tourmaline vein in the granite half a mile north-west of White Alice (3,862) is filled with alternating layers of dark blue tourmaline peach, and quartz with a smaller amount of tourmaline. Some of the quartz veins are comby, but there is little or no brecciation.

The next stage is represented by the brecciation of the vein-stone. A specimen from East Wheal Lovell illustrates this type (3,863). It consists of fragments of white milky quartz, with many fluid cavities, and filled with small tourmaline crystals. These are surrounded by fine dark bluish green peach, and some large crystals of brown tourmaline are also present in the slide, with their cracks and borders often fringed with blue needles. This tourmaline is frequently broken, and is probably of the same age as the early milky quartz. A few thin later quartz veins cut the whole mass. The blue tourmaline, therefore, is clearly later than the brown crystals, having filled its cracks.

The following specimen from Porkellis Moor (3,857) illustrates still more clearly the progressive products of infiltration. This is a brecciated quartz-tourmaline vein, in which white fragments of quartz are lying in a dark blue matrix of tourmaline peach. This quartz is white, milky, and contains vast numbers of fluid cavities, but little tourmaline. It is surrounded by a cementing material of finely granular quartz filled with blue or bluish green needles of tourmaline, and the whole mass is cut by later veins of clear quartz with small indigo-blue tints. The earlier quartz fragments are often crushed and give undulatory extinction; the quartz of the later veins is granular and uncrushed. There are thus three periods of infiltration, viz.:—

1. Quartz.
2. Peach.
3. Quartz with tourmaline.

Local foliation.—Besides the rude orientation of the granite to which attention has already been drawn, a more pronounced foliation has been occasionally set up both in the main mass and in some of the smaller sills that fringe its border.

In the neighbourhood of Kennal Vale, near Ponsanooth, the granite is very distinctly foliated for a distance of about half a mile from its margin. The orientation set up is very obvious, having a strike of about north-north-west, which corresponds to the trend of the "cleaving-way" joints. Here the orientation is no longer restricted to the parallelism of a number of the elongated minerals (porphyritic felspars) producing the "grain," but there

are definite planes in the rock which dip steeply towards the margin of the granite, and the mass is sometimes so foliated that its schistose character can be detected in a hand specimen. The foliation agrees in its trend and general hade with the corresponding planes in the slates which flank its margin. A specimen obtained one-sixth of a mile north-east of the Powder Mills, near Ponsanooth, is seen under the microscope (3,558) to be a sheared muscovite granite. The rock is pale coloured and contains very little biotite. The felspar is mainly perthitic orthoclase, much weathered with the production of secondary muscovite. Primary muscovite is common, and there are one or two grains of tourmaline, but no andalusite. In many places the rock shows cataclastic structures. The quartz is often broken up into a mosaic of interlocking grains. The amount of crushing varies in different parts of the section and is most pronounced in certain narrow undulating bands, along which there is often a layer of parallel scales of muscovite.'

About 200 yards north-north-west of Lower Tretharrup, in the district of Lanner, a fine-grained granite has been quarried. It occurs within the normal granite, and is in the nature of a contemporaneous vein. It is about 15 yards in width, but thins in a south-westerly direction. It behaves somewhat like an elvan, and hades steeply to the south-east. The normal, coarse-textured granite is rich in biotite. This mineral, however, is absent in the vein, a specimen of which, seen under the microscope (3,872), is a fine-grained muscovite granite, with a few crystals of brown and green tourmaline. The rock is very rich in muscovite, but contains neither biotite nor chlorite.

For the following analyses of the Carnmenellis granite we are indebted to Messrs. John Freeman & Co. :—

	Penryn.	*Carnsew.*
Silica - - - -	72·84	72·05
Alumina - - -	16·25	15·83
Ferric oxide - - -	·14	·39
Ferrous oxide - - -	1·49	1·50
Lime - - -	1·10	1·14
Magnesia -	·55	·51
Sodium oxide - - -	2·25	2·65
Potassium oxide - -	5·19	4·79
Moisture and loss	·63	·64
	100·44	99·50

SMALLER INTRUSIONS FLANKING THE CARNMENELLIS GRANITE.—The smaller granite intrusions which fringe the Carnmenellis mass are mainly confined to that portion of its western border situated between Crowan and the valley of the Cober. On the east two small examples occur near Budock, and another in the neighbourhood of Treluswell.

With the exception of the bosses near Budock, these marginal intrusions usually take the form of small sill-like masses parallel

to the granite border. They are marked by a texture finer than that of the main mass, and differ in mineral composition, owing to the presence or absence of tourmaline or of biotite. Some are true aplites, while in other cases the rock more properly falls under the category of greisen. Moreover, their structure shows an equal variation, some exhibiting cataclastic characters, and even foliation. An example of the latter is afforded by two sills that flank the granite margin at Treluswell, near Penryn. In the railway cutting these foliated sills are interposed between the slates, and appear to have participated in some of the stresses to which the latter have been subjected. They are about 30 yards distant from the granite junction, and share in the hade of the slates, which dip away from the main granite. Their foliation planes correspond with the cleavage planes of the slate between which they are intercalated. Microscopic examination (3,364), shows them to be fine-grained granite, cataclastic, and distinctly foliated. The quartz is all crushed, and in addition to felspar the rock contains both muscovite and biotite. The evidence favours their modification by pressure before final consolidation, the repeated intercalation with the slate that marks their upper junctions suggesting folding. It is possible, however, that the irregularities of the junctions may represent the original intrusion, and that the foliation may have been induced after solidification.

Between Trannack and Praze, sills of granite, often closely contiguous, are exposed in the cuttings of the railway. The absence of good sections in this district precludes a satisfactory examination of the granite margin, and it is probable that the sills drawn on the map, and which are almost entirely confined to the railway cuttings, quite inadequately represent the minor granite intrusions of this tract of country.

The largest mass noted is seen in the railway cutting above Wheal Trannack, at a distance of about 200 yards from the edge of the main granite. Although of variable texture, this marginal intrusion is chiefly of fine grain, often recalling the finer veins of the Carnmenellis granite. It is frequently studded, however, with porphyritic felspars, some of which attain an inch in length, but their occurrence is attended with great variation. Biotite is often very plentiful, and tourmaline is sometimes present. It differs from the main granite mass in its immediate vicinity, which is of coarse and uniform texture as far as its margin. On the valley slope, where a quarry has been opened, it is interbanded with the slate.

A small sill, a quarter of a mile west of Truthall, is seen under the microscope (3,934) to be a rather fine-grained schorlaceous greisen, which has been sheared, so that the quartz and felspar are often granulitic, the quartz showing undulatory extinction, and forming an interlocking granulitic mosaic. The muscovite is bent and dragged out. The shearing, however, is not visible in the hand specimen.

Another sill, occurring about half a mile west of Tregathennan, is a highly quartzose rock, containing very little felspar, and is

almost a schorlaceous greisen. It is fine-grained, with primary and secondary muscovite, orthoclase, plagioclase, and apatite (3,935).

A sill situated one-third of a mile east of Chynhale is a fine aplite (3,936), with decomposed felspar and quartz in a mosaic of very irregular interlocking grains. In the hand specimen a few blebs of quartz are visible. There is no tourmaline or biotite.

Carn Brea Granite.—This granite forms a lenticular mass, trending north-east and south-west for a length of about four miles between Redruth and Pendarves. It is clearly an extension of the Carnmenellis granite, being separated from the latter by a strip of killas with an average width of little more than half a mile, while in the neighbourhood of the Condurrow and Grenville mines the two granites more closely approach one another, the intervening killas occupying about one-eighth of a mile. The subterranean connection between the two masses is demonstrated by mining operations.

This granite forms the rugged and picturesque hill of Carn Brea, where its rude prismatic jointing and coarsely stratiform structure are admirably displayed. (Plate VII.) To the north-east, after crossing Church Coombe, it contracts to a thin tongue, which extends as far as Redrnth, about half a mile distant from the western margin of the Carn Marth granite. On the south-west, from Camborne Beacon to the neighbourhood of Bottetoe Bridge, it occurs as a narrow strip, converging to a point. For the latter part of its course, however, within the grounds of Pendarves, it does not protrude at the surface, and its boundaries can only be approximately drawn.

It is a tourmaline-muscovite-biotite-granite like that of Carnmenellis, and conforming to the same system of jointing, and includes a similar assemblage of contemporaneous veins of fine-grained granite or aplite. On the slopes of Carn Brea it is of coarse texture, but at The Rocks, between Camborne Beacon and Pendarves, where it contracts to less than 300 yards in width, the texture is finer, but it still contains porphyritic felspars up to an inch in length.

In a quarry about a quarter of a mile north-east of Bosleake the granite exhibits a singular regularity in the arrangement of the finer-grained aplite veins. The normal rock is of coarse texture, the felspars exceeding an inch in size. Tourmaline is scarce. Biotite is abundant, and also white mica, the latter often a lithia mica and occurring in large plates with pinkish hues. The aplite veins are marked by a strict parallelism with a dip of 30 deg. to the south-east, and are sometimes studded with large felspars identical with those in the adjoining granite. These finer veins vary in width from six inches to one inch. Moreover, there is a subordinate system of jointing parallel to them. The "cleaving-way" joints of the granite are N. 35 deg. W., with the larger felspars orientated in a like direction. The "tough-way" joints are about N. 45 deg. E. There is also a vertical system of fissuring parallel to the "tough-way" joints, which cut

through the aplites and contain tourmaline. The aplites are moreover disturbed by the subordinate system of parallel jointing already alluded to. The coarse granite in this quarry contains some fluorspar.

A quarry on the western border of the granite, about a quarter of a mile west-south-west of Camborne Beacon, shows a mixture of fine-grained biotite-granite and pegmatite. Amongst the granite large individuals of white felspar, of irregular shapes, and reaching a size of five or six inches, are abundantly interspersed.

The margin of the granite is exposed along the railway cutting between Brea and Penhellick, and a specimen obtained at the railway cutting near Cook's Kitchen Mine shows an unusual amount of mechanical deformation. Under the microscope (3,931) it is seen to be a granulitic fine-grained muscovite granite. The quartz is much crushed, and everywhere shows cataclastic structures, and the felspar is mainly replaced by aggregates of quartz and muscovite. There are a few grains of sphene and of brown tourmaline. The muscovite is often much puckered and bent.

About half a mile north-east of Camborne Station, and rather over 200 yards from the granite margin, a small dyke of fine-grained granite traverses a greenstone. It is a tourmaline granite, containing also a little biotite but no primary muscovite. Plagioclase is common in well-formed crystals, but the orthoclase and quartz are quite irregular.

The following analysis of the Carn Brea granite was made by Mr. J. A. Phillips*:—

Water { hygrometric	·34
Water { combined	·89
Silica	74·69
Alumina	16·21
Ferrous oxide	1·16
Ferric oxide	trace
Manganous oxide	·58
Lime	·28
Magnesia	·48
Potassa	3·64
Soda	1·18
Lithia	·10
	99·55

Specific gravity - - 2·64

CARN MARTH GRANITE.—The Carn Marth granite forms an irregular boss between two and three square miles in size. It extends from the eastern side of Redruth to St. Day, and from the vicinity of Mount Ambrose on the north to the southern slopes of Carn Marth on the south. Its southern margin approaches within

* *Q.J.G.S.*, vol. xxxi., 1875, p. 330.

about 130 yards of the Carnmenellis granite, in the neighbourhood of Pennance, while mining operations show that below the surface these granites still further approach one another, even if they are not actually contiguous Its boss-like shape, however, rather suggests an independent intrusion than an outlier of the Carnmenellis granite. Moreover, in spite of its general petrological relationship to the latter, its textural arrangement appears to be somewhat different, while tourmaline is also probably of more constant occurrence. The textural character of this granite is marked by the slenderness of the porphyritic felspars, a feature which appears to give it a distinct individuality as compared with the granites of Carnmenellis and Carn Brea, and it possibly represents an independent intrusion from the same magma basin.

This rock is likewise characterised by an excess of biotite, the muscovite being usually subordinate. In some cases, however, the two micas are more equally apportioned. It is rare, however, to find a section in which either tourmaline or biotite are not prominent constituents, and in this respect the granite markedly differs from that of Carnmenellis. In the quarries at Carn Marth the texture is often somewhat coarse, some of the felspars measuring 1½ inches by 1 inch.

In a quarry about 70 yards north-west of Carn Marth it is subject to considerable differentiation and banding is common, the rock being as a whole of somewhat coarse texture, but intermixed with a fine-grained biotite granite, which sometimes contains porphyritic felspars. This fine-grained porphyritic type may occur along the horizontal floors, or as irregular veins, and sometimes in large nodular forms. In some of this granite there are concentric selvages. In one instance a core of coarse dark granite three feet in diameter is bounded by a thin ring of schorl; this is succeeded by a zone one to two inches wide of felspar, that passes outwards into granite very rich in tourmaline, parts of which are highly felspathic.

In another instance the successive rings of schorlaceous and felspathic material contain felspars with a uniform orientation independent of the concentric structure.

In some cases the core is of fine-grained schorlaceous granite, surrounded by rings of coarser normal granite. The interbanding and concentric structures are not constant, but the various segregatory types are sometimes imperfectly mixed. A few of the vertical bands that coincide in direction with the "tough-way" joints contain porphyritic felspars two to three inches in size.

III. Elvan.

Elvan dykes are abundantly distributed in the districts of Camborne, Redruth, Gwennap, and Chacewater. To the east of Truro and the Carrick Roads they have not been detected, and they are likewise absent in the belt of country that fringes the north coast. In the remaining area, lying approximately south of Carnmenellis, their occurrence is sporadic. The tract in which the elvans are conspicuous, extending approximately from Camborne

to Baldhu, also represents the principal metalliferous region. Moreover, the trend of the elvans (about east-north-east) corresponds with the general direction of the mineral lodes. Elvan dykes occasionally trend in other directions, but this is far from common. While some can undoubtedly be traced for two or three miles, the bulk of these dykes are continuous for only very short distances, and it is probable that the map somewhat exaggerates their general continuity. They vary from a few feet to many yards in thickness, while in some instances they attain great dimensions. They are usually very steep, and the hade in the majority of cases is to the north-west. A considerable number traverse the granite and a few cut the greenstones. No instances, however, have been observed during the progress of the survey where the elvans and mica traps are in juxtaposition, and their relative ages, therefore, cannot be definitely fixed.*

Their petrological relationship to the granite is so obvious that there can be little doubt that they represent its dyke phase. They exhibit, however, considerable variation both as regards texture and mineral composition. In their resistance to weathering they differ considerably, some affording excellent building stone, while others have so decomposed as to be worked for clay. Their colour ranges from pale grey to pink, while some are dark and of a greenish hue. They are frequently bounded by a finer-grained selvage, and in exceptional cases the rock is somewhat banded. So far as this district† is concerned, they are characterised by a micro-granitic ground mass, which varies in texture from fine to fairly coarse. In this matrix phenocrysts are usually scattered, and they are often idiomorphic, and consist of quartz, felspar, generally perthitic orthoclase, sometimes plagioclase, biotite, and occasionally muscovite. The porphyritic constituents may all be present, or be represented by one or two of these minerals only, but quartz is seldom absent, while occasionally no porphyritic minerals are enclosed. The porphyritic quartz is often corroded at its edges, while the felspars are frequently wholly or partially decomposed, with production of secondary white mica, and the biotite frequently passes into chlorite. Original white mica is not common as a porphyritic constituent. The minerals of the groundmass are quartz, felspar, usually orthoclase, white mica, biotite, and apatite. Pinite is rare, but tourmaline is often present, sometimes as an original constituent, but generally as a secondary infiltration product. The groundmass often contains micropegmatite and is occasionally micropoikilitic. Very frequently its felspar has been more or less completely replaced by a fine-grained mixture of muscovite and quartz. Most of the elvans are granite-porphyries or micro-granites, and some are aplites, while others belong to the granophyres. The schorlaceous varieties are mainly confined to

* Mr. Collins, however, has described a junction that will be referred to in the description of the mica traps.

† Mr. J. A. Phillips has described the general petrographical characters of the Cornish elvans. *Q.J.G.S.*, vol. xxxi., 1875, p. 334.

the great belt in which the mineral veins are situated. Tourmaline, when original, is usually of the ordinary brown colour, while the blue varieties are more commonly found as secondary infiltration products, the latter tint either pervading the entire mineral or forming a border around the brown individuals. In the process of mineral alteration by impregnation with silica and schorl, the felspar of the rock has often entirely disappeared, and biotite has been wholly or partially replaced by chlorite. In some mineralised elvans, however, the biotite has not been attacked, and apatite has also offered considerable resistance to decomposition.

As these dykes are so numerous, only a few of the more important will be described. A typical elvan is quarried at Nansavallan Wood, about a mile to the south-west of Truro. This dyke, which hades steeply to the west, is probably at least from 25 to 30 feet thick. It is a granite porphyry, with porphyritic felspar, quartz, and biotite. These felspars attain an inch in length, while occasionally the biotites are equally large. The quartz occurs in bleb-like forms, which sometimes exceed a quarter of an inch. The groundmass of the rock is rather coarse. For several feet from the edge of the dyke the porphyritic crystals are absent, and this portion of the rock is sometimes banded (3,358).

The elvan that is quarried at Enys is of similar type, but finer in texture, and hades about 70 deg. to the east-south-east.

A dyke traverses the granite for over a mile between Towntanna and Trevales—on the old map it has been drawn for a mile farther in a south-west direction, but no evidence is at present available for such extension. At the quarry at Towntanna it occurs as a medium-grained grey elvan, 25 to 30 feet in thickness, with porphyritic felspars up to half an inch in size. It is irregularly jointed, with the prominent joint planes oblique to the horizontal. Under the microscope (3,360) it is seen to be much decomposed, with many small phenocrysts, and only a little groundmass. This dyke, where it is quarried near Trevales, is more regularly jointed, some of the "quartering-way" joints ("floors") of the granite being continuous into the elvan. Moreover, one of the main joints of the latter corresponds with the "cleaving-way" joint of the granite. The more horizontal joints, however, of the elvan are uneven, and cut one another obliquely. The dyke is more or less vertical, with a junction not quite regular. Its margin is veined with hæmatite, which partially stains the dyke, imparting a red colour. It is here about 18 yards in width, and its face is slicken-sided. There are some large individuals of porphyritic felspar and some quartz blebs, but the biotites are small. Under the microscope (3,361) the groundmass is seen to be micro-granitic.

An elvan which attains abnormal dimensions extends from Greensplat to Lanner Moor. From Greensplat it follows a westerly direction by Frogpool, Pulla Cross, and Gwennap. It passes to the south of Trevince, and soon after curves round in a west-south-west direction to Lanner Moor. It varies in

width from 150 to at least 300 yards. This dyke conforms to the normal type, and contains porphyritic crystals of quartz and turbid orthoclase in a microgranitic groundmass of quartz, felspar, and secondary muscovite. Many of the felspars are entirely replaced by white mica (3,834). At Frogpool the phenocrysts are quartz, felspar, and biotite, and the matrix is micropoikilitic (3,442). To what extent the width of outcrop represents its thickness cannot be ascertained, as its hade is uncertain. The porphyritic felspars are sometimes of one-half to one inch in size, and the quartz is frequently idiomorphic. A good section is afforded by the road cutting in the hill above Comford. On its eastern boundary, two smaller dykes in the neighbourhood of Coldwind may possibly represent branches, but the evidence is insufficient to connect them with the large mass, and a like obscurity attends its western limits at Lanner Moor.

The elvan dykes between St. Day and Perranwell are extremely difficult to trace. Information from mine plans has been utilised where available, but as many bands encountered underground do not appear at the surface, this source of information is far from reliable. A few of the dykes from this area will now be described.

A band that can be followed from the vicinity of the large Gwennap elvan, from Greensplat to Greenwith, and which is possibly identical with the elvan extending from Higher Carnon to Killiow, is seen at the quarry near Pencoose to hade 30 deg. to the north-west. It is about 20 to 30 yards in width, and contains porphyritic felspars an inch in length, with smaller quartz blebs and mica in a fine-grained grey matrix. It is traversed by strong splitting planes hading 60 deg. to the south-east. In the quarry near Greenwith the rock is somewhat fresher, while under the microscope (3,441) it is seen to contain phenocrysts of corroded quartz, weathered felspar, and decomposed biotite, in a groundmass which is granular crystalline, composed of quartz and felspar, with secondary muscovite, chlorite, and calcite. Many of the elvans of this district occurring in the metalliferous area have been modified by mineral infiltration. A dyke at Wheal Maid is a schorlaceous quartz-porphyry, containing small, slightly corroded blebs of quartz, with plates of perfectly colourless muscovite, in a matrix which is a micro-granitic aggregate of quartz and untwinned felspar filled with scaly secondary muscovite. Tourmaline occurs throughout the rock in fairly large prisms, which in their centres are brown, but at their edges are blue with strongly-marked pleochroic halos, giving colours ranging from pale yellow to dark blue. Smaller prisms also occur, mostly blue, and in some instances a brown tourmaline is enclosed in a quartz phenocryst, but blue borders are then absent. Grains of zinc-blende are also scattered through the rock (3,836).

A dyke near Sparry Bottom has undergone considerable silicification. It is a dark coloured schorlaceous quartz-porphyry (3,842) containing porphyritic crystals of quartz which are not highly idiomorphic. The groundmass is chiefly quartz and muscovite, felspar being almost entirely removed, a change comparable to that

taking place in the formation of greisen. Tourmaline is not abundant; it occurs mostly in small irregular prisms of yellow-brown colour, rarely bluish, and never fibrous. A specimen taken from another part of the dyke shows yet further alteration (3,841), but contains abundant blebs of the original quartz phenocrysts. The whole rock has been filled with bluish tourmaline, which forms veins and irregular patches, and it is, moreover, fractured and distinctly brecciated. Areas of granular quartz are frequently developed in the groundmass, the remainder consisting of an aggregate of fine mica and minute quartz grains, while no felspar appears to be left. The tourmaline, in very fine needles mixed with quartz, resembles the "peach" of the veinstones, but the section shows no tinstone. Another elvan from near the same locality (3,845) is more thoroughly silicified, but contains a few conspicuous quartz crystals, one of which is an idiomorphic double pyramid. It consists of a fine mosaic of quartz, chlorite, and muscovite, with iron ores, pyrites, and limonite, and was probably originally a fine-grained non-porphyritic elvan. These rocks bear the same relation to the normal elvans as do the greisens and schorlaceous greisens to the granite.

In the Chacewater district, lying immediately to the north, a well-known elvan has long been quarried at Saveock Water. This rock is characterised by schorlaceous nests and patches which sometimes attain an inch in size. The dyke hades north-west, and the quarry is traversed by a cross course. The porphyritic constituents are felspar, which are about a quarter of an inch in size, and quartz blebs. Under the microscope (3,833) the phenocrysts of quartz and orthoclase are seen to be idiomorphic, the quartz showing few signs of corrosion and filled with large fluid cavities with mobile bubbles. Many of these cavities are negative crystals, and some contain small transparent cubes. The porphyritic felspars are much decomposed, but are mainly perthitic orthoclase, although some are possibly oligoclase. A curious feature is the presence of porphyritic groups of coarser micropegmatite. Some of the porphyritic quartz is surrounded by an ill-defined narrow halo of smaller quartz grains in optical continuity. The matrix is a microgranitic aggregate of quartz, cloudy untwinned felspar, and fine scales of muscovite. Chlorite is also present, often in radiate bundles, fairly dichroic. The tourmaline is practically confined to the rounded patches seen in the hand specimen. It forms small irregular grains, highly pleochroic, in shades of blue, bluish green, and pink, and appears to fill up the interstices between the grains of quartz, which constitute the remainder of the aggregates. It never yields perfect crystals and occasionally forms radiate groups. The structure of these patches is not poikilitic, but in some parts of the section there are small poikilitic areas. Larger crystals of quartz occur in them, evidently phenocrysts, and lead to the conclusion that these rounded spots are due to local tourmalinisation. Another well-marked dyke traverses Kerling Downs, where it has been quarried. This is a greenish elvan, rather fine grained, and dipping about 40 deg. to the north-west, and sometimes decomposes to a rich

orange colour. Under the microscope (3,848) this rock retains no igneous structure, except, perhaps, the chloritic pseudomorphs after idiomorphic biotite. It consists entirely of irregular grains of quartz with highly sinuous borders, turbid with innumerable enclosures of muscovite and of chlorite in small scales, sometimes radiate, but mainly quite irregularly dispersed. Felspar is absent, but some of the apatite remains, and the original quartz grains may occasionally be traced, surrounded by an extensive growth of newly-deposited silica, with which it is in optical continuity. Pyrites and limonite are present in small quantity. This rock furnishes a good instance of silicification by post-volcanic processes.

A silicified elvan that is quarried about half a mile south-west of Chacewater has been a fine-grained non-porphyritic pinitiferous biotite granite. It is about 5 or 6 yards wide and apparently hades to the north. It contains black scales of biotite, which under the microscope (3,835) are seen to be weathering to chlorite and rutile. One large pseudomorph, consisting of scaly muscovite and chlorite, belongs to the pinite group. The mass of the rock consists of irregular grains of quartz, the felspar being almost completely replaced by silicification. Veins of granular quartz traverse the section, and in places this mineral forms nests which contain small needles of tourmaline. A peculiar clear green chlorite occurs in circular patches consisting of radiate bladed crystals, usually closely related to the infiltrated quartz and tourmaline, so that it may be regarded as a mineral of subsequent aqueous deposition, and is very similar to the chlorite of the tin-bearing veins.

Another good example of a silicified elvan occurs in the same locality. Under the microscope (3,844) it shows many corroded quartz phenocrysts, and patches of scaly brown biotite absolutely fresh, some pyrites, apatite, and iron oxides. The matrix of the rock is a mosaic of rather large irregular quartz grains, which are filled with fine flakes of secondary muscovite, and no felspar is present. The secondary quartz of the groundmass surrounds the original quartz phenocrysts, usually in the form of a broad border in optical continuity with the central crystal, but easily distinguished from it by its turbidity and by the large number of enclosures which it contains. It is clear that the whole groundmass has been reconstructed under the action of percolating siliceous solutions.

Between Chacewater and the Camborne district there are numerous elvans that can be more continuously traced than usual. They lie mainly on the north side of the Carn Brea granite, and are most conspicuous in the tract between Pool and the western edge of the map, in the vicinity of Penhale Moor. To the east of Higher Cardew, near Redruth, a band is quarried on the margin of the Carn Marth granite, which it pierces. It is a porphyritic pinitiferous elvan (3,837), the phenocrysts being orthoclase and biotite, the latter decomposed into chlorite, together with pinite in well-formed idiomorphic small six-sided prisms. The band which cuts the granite further to the east, and which has been

quarried close to the main road, is possibly a continuation of the dyke last described. It has, however, suffered a great deal of alteration from mineral impregnation. It is a schorlaceous quartz porphyry, containing a considerable amount of orthoclase, with quartz, muscovite, tourmaline, and chlorite. The rock has been porphyritic, with a rather coarse-grained quartzo-felspathic groundmass, but this has suffered largely from silicification, and has become impregnated with quartz, tourmaline, and chlorite. The tourmaline is mainly brown, but sometimes bluish yellow, grey or colourless. The chlorite is of the grey-green variety with high polarisation colours characteristic of the tin veins (3,846).

A dyke that pierces the Carn Brea granite, a little to the east of the Castle, is unusually coarse in texture, owing to the large number of phenocrysts. This is a granite-porphyry in which porphyritic crystals of quartz, orthoclase, and chloritised biotite are lying in a microgranitic groundmass of quartz, felspar, and scaly muscovite. This elvan is about 12 yards wide, and nearly vertical. Some of the porphyritic felspars exceed an inch in length, and there are schorlaceous patches 2 or 3 inches in size. On either side there is a chilled margin against the coarse granite about 2 or 3 feet wide, but in this fine marginal portion porphyritic felspars are occasionally scattered.

At Tuckingmill a pinitiferous elvan contains rounded nodules of quartz and blue tourmaline. The phenocrysts are quartz, orthoclase, and pinite, and the groundmass is micro-granitic with scaly muscovite (3,941).

An elvan from Higher Rosewarne of the silicified type is seen under the microscope (3,942) to contain small phenocrysts of orthoclase, quartz, and chloritised biotite, in a turbid and flinty-looking groundmass, which, between crossed nicols, breaks up into irregular rounded patches of quartz, with intervening areas of fine decomposed products.

The railway cutting west of Camborne Station affords an excellent example of an elvan intersecting a greenstone. The dyke which hades to the north is the usual type of granite porphyry. Phenocrysts of quartz, perthitic orthoclase, and chloritised biotite lie in a fine microgranitic groundmass, which in places is micro-poikilitic, and apatite is common (3,939). The north-easterly continuation of this band in the direction of Camborne is obscure, but to the south-west it appears to run for some distance through Higher Penponds and Barripper.

Another elvan traverses the greenstone for a considerable distance between Weeth and the railway cutting near the western edge of the sheet. Other localities where these dykes cut the greenstone are in the grounds of Rosewarne, and on the mineral railway track a little to the east of the latter locality. The elvans occurring to the south of Camborne between Beacon Hill and Gear Farm cannot be satisfactorily connected, owing to the paucity of the sections and the somewhat conflicting evidence obtained from the mining plans.

On the east side of Beacon Hill a large quarry has been formerly worked, in which an elvan, about 30 yards wide,

appears to underlie north. The rock, where seen, is fine grained, but this texture may possibly represent its margin ; otherwise if this is the same dyke that occupies the railway cutting at Pengegon Coombe, just beyond the granite margin, it would appear to have undergone a considerable change in texture. It there underlies north, and is so coarse in grain that its decomposed portions might readily be mistaken for granite, the felspars often reaching three-quarters of an inch in size.

The dykes that pierce the Carnmenellis granite are most abundant along its northern margin, especially at Buller Downs, Four Lanes, and Croft Michell. Between Troon and Bolenowe Crofts a grey elvan occurs, with the usual northerly hade, and contains porphyritic felspars up to an inch in size, with some tourmaline.

A very coarse-textured band runs from Bolenowe Moor to Croft Michell. It is a granite porphyry, 30 to 40 yards in width, hades steeply to the south, and presents chilled margins to the granite. A little to the east of Trebowland an elvan has been traced through Tredeague as far to the south-west as Treweege. It varies in texture from coarse to fine grain, and contains tourmaline in varying proportions, while in the coarser zones the porphyritic felspars reach three-quarters of an inch in size. Under the microscope (3,838), this rock is a schorlaceous granite porphyry, with porphyritic quartz, orthoclase, and biotite, in a rather coarse groundmass of microgranitic quartz and untwinned felspar. There is a little brown tourmaline, and blue needles of that mineral form occasional radiating bunches. A somewhat similar rock occurs a little to the south between Angear and Treskewes, a specimen from which (3,849) is a brecciated coarse elvan with tourmaline and muscovite, and traversed by veins of quartz and tourmaline. Short rough prisms of brown tourmaline are common, but the blue variety is rare, except in the quartz veins. The groundmass is coarsely microgranitic; most of the muscovite and tourmaline are primary, and large irregular apatites are rather frequent. An elvan which occurs about three-quarters of a mile south-west of Carnmenellis somewhat resembles the dyke just described from Trebowland. Although not traced in the intervening area, which exceeds a distance of two miles, it seems to be on the same line. It is grey to pink in colour, contains porphyritic felspars up to three-quarters of an inch, porphyritic quartz, and much tourmaline, forming nests of stellate individuals as in the Trewbowland dyke. Under the microscope the rock is a schorlaceous granite porphyry (3,840), with numerous crystals of idiomorphic quartz and orthoclase, the latter having sometimes plagioclase at their centres. Biotite occurs also in large crystals, but is not common, and the presence of pinite is doubtful. The groundmass is microgranitic, and is filled with small muscovites, while blue tourmaline with quartz forms certain rounded patches. Tourmaline is often radiate, but is usually granular, and the pleochroism of some crystals ranges from pale pink to dark indigo blue. Sometimes this mineral occurs in the interior of felspar crystals, but it is mainly confined to the groundmass.

A fine-textured grey elvan, belonging to the aplite group, occurs at Tresevern Croft, where it appears to extend for at least half a mile. After being lost sight of for a mile, it again appears at Polmarth, and can be followed for about three-quarters of a mile in the direction of White Alice. Whether the dyke is really continuous with that at Tresevern is uncertain. It is of precisely similar character, however, and is on the same line. Moreover, in neither locality would its presence have been detected were it not for the quarries and the assistance of local information. As in the quarry at Tresevern it pinches out entirely at its southern end, it is probable that the dyke reaches the surface in discontinuous strips. In this quarry it is about 15 yards wide. At the northern end it deflects to the east, and becomes intermixed with the granite, but there is always a sharp distinction between the two rocks, and pieces of granite are often enclosed in the dyke. The horizontal joints of the adjacent granite are continued through the elvan. The dyke is fine grained and of a pale grey colour, with a few small phenocrysts of clear quartz, while porphyritic felspars are rare and always small. Under the microscope (3,831) the rock has the structure of an aplite, and consists of small irregular crystals of untwinned felspar and of quartz, the felspar occasionally showing rudimentary crystalline form. Much muscovite is scattered through the slide in small scales, apparently secondary; but there are also occasionally idiomorphic plates, which are, perhaps, primary. Plagioclase is practically absent. There are one or two small porphyritic crystals of quartz and felspar, the former not strongly idiomorphic, the latter well formed, but much decomposed. The rock is a very fair example of an aplite. In the quarry at Polmarth the elvan is precisely similar in appearance, and, like the rock at Tresevern Croft, pinches out to the south-west, after which it again widens. It is about 12 to 15 yards in breadth, and hades very steeply to the north-west. The adjacent granite is partly mineralised, due to secondary infiltration, the vertical joint separating the granite and elvan forming a marked line of mineralisation. To the north-west of White Alice this dyke is again exposed in a small quarry with a similar hade, where it is about 12 feet wide. It may be considered as a type of elvan in which the felspar was especially abundant, but has been extensively replaced by secondary quartz and white mica (3,832).

About half a mile south of Tregolls a fine-textured grey elvan occurs, in which porphyritic felspars are rare, and, as seen in the field, bears a strong resemblance to the dyke just described. Under the microscope (3,847), irregular phenocrysts of orthoclase and quartz are seen in a groundmass of quartz, felspar, muscovite, and chlorite, some of the latter being after biotite, and much of the muscovite is also secondary. Tourmaline is only represented by a few small grains, but apatite is fairly abundant. Nearly two miles further to the south-west, but along the same line, this dyke apparently reappears between Wheal Enys and Bodilly Veor. It has been quarried about one-third of a mile north-north-west of

Crelly, where the width is about 20 to 25 yards, and the hade is steep to the north-west. Under the microscope it is seen to be a fine-grained, pale grey aplite, consisting of quartz and felspar in small irregular granules, mixed with minute scales of muscovite. There are one or two large idiomorphic felspars, and here and there an idiomorphic crystal of muscovite.

At Polcrebo an elvan about 16 yards in width crosses the railway. It is porphyritic, with a micrograntic groundmass of quartz, felspar, and scaly muscovite. In this lie phenocrysts of quartz, perthitic orthoclase, graphic intergrowths of quartz and felspar, and biotite weathered into chlorite. A few of the phenocrysts are plagioclase, and there is one micaceous aggregate, suggesting pinite (3,938).

An elvan which in the field resembles a very fine-grained granite is quarried at Praze Station. It is grey in colour and of very even texture, but occasionally a porphyritic felspar of larger size is seen. This dyke, which is from 15 to 20 yards in width, hades to the north. It has not been observed within the granite which is closely adjacent, but it extends in a south-westerly direction to the margin of the map at Little Drym. Its passage through the park at Clowance can be followed by the line of pits from which stone has been formerly raised. It has also been quarried between Clowance Wood and Wheal Sarah. Under the microscope (3,946) it is seen to contain many small phenocrysts of felspar and of quartz, in a groundmass which is partly micrographic and partly microgranitic. Both biotite and muscovite are present. Dr. Flett observes that micropegmatite is unusually common in this rock for a Cornish elvan, and generally forms well-developed halos around the smaller irregular phenocrysts. This rock belongs to the granophyre group. The elvan that is quarried near the roadside between Trevoole and Trenoweth closely resembles the dyke at Praze Station in outward appearance, but contains in addition small nests of tourmaline.

In the railway cutting, about one hundred yards south-east of Praze Station, an elvan appears to pierce a fine-grained tourmaline granite. This dyke (3,944) is the usual type of granite porphyry, in which the quartz phenocrysts are slightly corroded. One or two crystals of tourmaline occur enclosed within porphyritic felspar.

In the region bordering the north coast two elvans have been traced for considerable distances, one passing through Menagissey, and the other extending from Treswithian Downs to Mawla. They both hade to the north-west, and sometimes, in the case of the latter, at a very low angle, as may be seen at Illogan. In these dykes the original orthoclase phenocrysts have frequently disappeared. Under the microscope the original quartz phenocrysts are bounded by a secondary outgrowth in optical continuity, while the felspars occasionally exhibit a similar structure (3,803, 3,804). Another group of dykes, extending from near Camborne to the western edge of the sheet, resembles the former, but according to Mr. Dixon their northerly hade is less, their felspars are less prone to alteration, and the outgrowths of the quartz phenocrysts are not constant. A further group occurs to the south of the latter,

to which it is oblique, having a trend more approaching east and west, and in some cases hading to the south. Mr. Dixon observes that their matrix is generally coarser, that phenocrysts are rare, and that greisen and kaolin have been developed associated with tinstone. One of the latter type intersects a dyke of the preceding group, and this evidence of posterior age, together with their pneumatolytic alteration, has led Mr. Dixon to the conclusion that the groups represent two successive periods of intrusion, the interval between which was possibly greater than that separating the latter injections from the metalliferous impregnations with which they were subsequently charged.

Elvan branches occupying north-north-west fractures occur in the cuttings west of Two Barrows, and north-west of Coswinsawsin.

The following analysis of the elvan from Newham Quarry, near Truro, was made by Mr. J. H. Collins, who describes it as a remarkably fine-grained elvan, showing almost no porphyritic character* :—

Water (hygroscopic)	·24
„ combined	2·04
Silica	72·88
Alumina	14·47
Ferric oxide	2·45
Manganous oxide	·82
Lime	·10
Magnesia	trace
Potash, Soda	7·15
Lithia, Fluorine	trace
	100·15

IV. Mica Traps.

General Description and Lithological Characters.—The mica traps of this area were formerly included amongst the elvan group, but De la Beche refers to them as greenstone; one of this type was described as an elvan from Trelissick by Mr. J. A. Phillips.† Later the mica traps of Cornwall were described by Mr. J. H. Collins,‡ who states that Mr. A. K. Barnett was the first to draw attention to this class of dyke in the Truro River. Subsequently the mica traps of this particular area have been described by the author.§ The course of some of these bands is shown on the old map by faint dotted lines.

In this sheet they appear to be entirely confined to the minette

* *Journ. Roy. Inst. Corn.*, vol. vi., p. 419.
† *Q.J.G.S.*, vol. xxxi., 1875, p. 337.
‡ *Journ. Roy. Inst. Corn.*, part ii., vol. viii., 1884.
§ J. B. Hill. *Trans. Roy. Geol. Soc. Corn.*, vol. xii., part vii., 1902.

family, that is to say, the two principal ingredients are orthoclase felspar and biotite, while apatite, quartz, and carbonates form the principal accessories. Augite has been rarely detected, and in these cases the rock is more correctly designated as augite minette. Owing to their advanced state of decomposition the felspars are not always sufficiently well preserved for identification, and it is possible that kersantites may be included in the group. In their field behaviour they bear a close resemblance to the lamprophyres of the Scottish Highlands, especially in their irregular sill-like characters and in their inclusions. In Cornwall, however, they are far more decomposed, but this character is shared in common with Cornish rocks generally. These rocks are similar in composition, state of preservation, geological age, and mode of occurrence to the lamprophyres of Gümbel, which occur as small dykes (usually running N. and S.) in the Palæozoic strata of the Fichtelgebirge, Thüringer Wald and Voigtland, that occur in strata as high as the Culm measures.* In the South of Scotland and the North of England they pierce Lower Palæozoic rocks, while in the Scottish Highlands they are allied to the newer granites, and may possibly be of Lower Old Red Sandstone age. In Cornwall Mr. J. H. Collins† considers them to be anterior to the granites, an opinion that finds some support in their having undoubtedly shared to some degree in the stresses that have affected the district, as will be shown later. On the other hand, rocks of this class in Devonshire have been found by Mr. Ussher to pierce the Permian.

The minettes do not occur within the granite aureole, nor do they exhibit metamorphism other than that resulting from atmospheric decomposition. They are never granulitised, but there are instances in which the micas have been bent and contorted. The biotite is sometimes bleached to a pale white colour, and in some instances this mineral has been entirely replaced by chlorite. They present a rusty brown aspect in the field, and are so weathered that fresh specimens are obtained with difficulty. They occur as sills and dykes that can be followed for very short distances among the slates, on which they have effected a limited amount of contact alteration, confined to the induration of the marginal slate for a width of six or nine inches. Their intrusive character is apparent; the same mass which lies between the strata as a sill may suddenly divert its course and behave as a dyke, while small veins penetrate the adjoining strata. They vary from a foot in width to fifty yards, but the latter does not correspond to the thickness of the sill, which is probably considerably less. They frequently display spheroidal weathering, the more solid cores being encircled by concentric outer layers of exfoliating material. Flow structure is not uncommon, especially in the finer-grained marginal portions. In some rocks exhibiting fluxion

* Teall, "British Petrography," p. 351.

† *Journ. Roy. Inst. Corn.*, vol. xiii., p. 203. Mr. Collins considers the mica traps to have been injected "about the close of the Devonian period."

the spheroidal cores are elongated in the direction of flow, while rounded quartz inclusions lie with their long axes in a corresponding position. Notwithstanding their decomposition, the mineral constitution of these rocks can generally be recognised as a medium-grained admixture of biotite and felspar, while inclusions of quartz and crystalline felspathic rock are characteristic, and slate fragments are frequently seen. The inclusions both of quartz and felspar are of rounded, angular, or even of rectangular shape. Notwithstanding the abundance of quartz inclusions, this mineral does not appear to enter largely into the composition of the matrix. They vary considerably in the distribution and abundance of felspar, some of the fresher parts appearing to be made up almost entirely of this mineral. They differ likewise in texture, some corresponding to coarse-grained dolerites, while others assume the texture of basalt. In the coarser sills the biotite plates retain their normal dimensions in the fine-textured marginal portions.

They appear to have been intruded after the slates had been cleaved, but before the cessation of the stresses. This may to some extent account for their occurrence in discontinuous patches. Some of their joint planes are parallel to the movement planes in the adjoining slates, and there is a tendency to a parallel structure and orientation corresponding to the latter. The minor faults in the adjacent killas have often affected the mica traps and heaved them. They do not penetrate the cross courses (N.N.W. faults) and are almost certainly older than those fissures.

Distribution and Field Relations.—The mica traps are of sporadic distribution in a narrow belt of country running approximately north and south across the map, on the horizon of the Carrick Roads and the continuation of the Fal estuary as far as Truro. In that tract these rocks occur at the following localities, viz., Pendennis Point, Penryn, on the coast of Carrick Roads below Messack; on the River Fal at Channals Creek, and on the coast below Pill Farm (south of Trelissick), and at the entrance of Cowlands Creek and of Lamouth Creek; at Higher Trelease and Penpoll, at the western mouth of Lambe Creek, and on the shore below Penpoll Wood. To the north-west of Truro they occur near Gloweth, Boscolleth, and at Shortlane End.

Of these various exposures those occurring on the coast are alone susceptible of critical study, the inland localities yielding only the decomposing surfaces of their outer crusts.

One of these mica traps, originally noticed by Mr. A. K. Barnett,* was analysed by Mr. J. A. Phillips,† and subsequently by Mr. J. H. Collins.‡ The following analysis and description of this rock is taken from Mr. Phillips' analysis of the rock from Trellissick Creek, north of Carrick Roads:—

* *Report Miners' Assoc. of Cornwall and Devon*, 1873
† *Q.J.G.S.*, vol. xxxi., 1875, p: 335.
‡ *Trans. Roy. Geol. Soc. Cornwall*, vol. ix., p. 221

Water	hygrometric	·34
	combined	6·11
Silica		47·35
Alumina		20·60
Ferrous oxide		1·60
Ferric oxide		3·10
Manganous oxide		trace
Lime		4·72
Magnesium oxide		6·12
Potash		6·29
Soda		3·58
Fluorine		trace
		99·81

Specific gravity - - 2·70

Mr. Phillips remarks that this elvan belongs to the north and south class. The width is about 30 feet, " and its colour varies from yellow or buff to a dark chocolate-brown, in accordance with the less or greater degree to which the iron present has become peroxidised. Its general appearance is that of a rock composed of a large quantity of mica, with a little felspar, enclosing occasional crystalline fragments of quartz."

" Under the microscope thin sections are seen to consist of a nearly equal mixture of quartz, felspar, and brown mica, enclosed in a felspathic base. The felspar is monoclinic, and the quartz contains a few small gas-cavities; but no well-defined fluid-cavities containing bubbles were observed."

Dr. Teall* records that a section in the British Museum, prepared from a rock in the same locality, contains a nearly colourless augite, abundant apatite, and octahedra of magnetite, in addition to the constituents mentioned by Mr. Phillips, and that the rock is a typical augite minette.

The dyke described by Mr. Phillips is in all probability the mass that strikes the coast about half a mile S.S.W. of Trelissick. It is here about 50 yards in width and cuts the killas at low angles. Its southern junction is dipping at an angle of 10 deg., while its northern wall hades at an angle of 30 deg. in the opposite direction. The latter margin is highly disturbed, and some of the mica trap is seen abutting against the slate at a distance of 12 yards from the main junction, which is apparently marked by a small thrust. The rock is much decomposed and displays spheroidal weathering. The matrix is an admixture of biotite and felspar, but it contains quartz inclusions two or three inches in size and pegmatite veins an inch in width. The quartz inclusions are often rounded and sometimes brecciated. Some of the spheroids are bound by material showing fluxion structure. It has a narrow selvage of finer-grained material confined to a few inches in width, in which the biotite flakes, however, are still of

* "British Petrography," pp. 353 and 355.

large size. It indurates the adjoining slate for a distance of eight or nine inches. The parallelism of its joints to those of the adjoining slates, the brecciation of some of its quartz inclusions, and the character of its northern junction, points to its having shared in some of the disturbances that have affected the killas. A specimen examined under the microscope (3,365) shows a large quantity of biotite in long broad laths, some of which are bent, and variations from striated laths, greenish to brown in colour, to dark brownish decomposed masses devoid of structure. Apatite in elongated prismatic and in transverse sections is very abundant and forms a striking characteristic of this rock. Turbid felspar without striation, probably orthoclase, seems to behave as a groundmass, together with calcite and quartz; sphene is also present. It contains likewise a green decomposition mineral, in which faint cleavage traces are discernible, as a pseudomorph, that may possibly represent augite.

Two small sills are seen further south along the coast, one to two feet in thickness, about 150 and 560 yards distant respectively, the former of which has been split by earth movements, while about 70 yards north of the large intrusion a sill 6 feet in width has been involved in the faulting of the slate. It is probable that the resistance offered by the dyke has given rise to the fracture along its junction. At its base the rupture is slight, but its upper junction is accompanied by much dislocation and contortion of the slate, while the sill itself has suffered from the disturbance. On the north side of Channals Creek, in the immediate vicinity, a 4-foot sill is seen 50 yards east of the Fish Pond, and about 8 yards farther east another about 2 feet in thickness, while yet another about 4 feet wide occurs about 200 yards east of the same locality. The last three dykes are highly decomposed, and these, together with those previously described, are intruded in the Falmouth series. On the south side of Channals Creek these rocks are not at present visible, although, according to Mr. Collins, four distinct bands were seen by him in 1878,* which are probably now concealed beneath the mud.

A good example is furnished on the east side of the Carrick Roads, about 1,000 yards north of Messack Point, which also occurs within the Falmouth series, and varies in width from 3 to 5 feet. Its intrusive character is obvious, as veins extend into the adjoining slate. The sill exhibits fluxion structure, more especially on its margin, and both the spheroids and the majority of the rounded quartz inclusions that occur up to 2 inches in size lie with their long axes parallel to its walls.

The mica trap at Pendennis Point, near Falmouth, skirts the coast for a considerable distance below high-water mark, so that its relations to the adjoining Portscatho beds are exceptionally clear. This band, with an average width of about 6 feet, after behaving for some distance as a sill, suddenly deflects to the north and cuts transversely across the strata as a dyke. It has been

* *Journ. Roy. Inst. Cornwall*, vol. viii., p. 194.

heaved slightly by one of the numerous small faults that traverse the slates, and its veins penetrate the adjoining strata. The rock is highly decomposed, and the biotite has been bleached to a pale white colour resembling muscovite. A marked characteristic of this rock is its pronounced veining and the abundant inclusions of quartz, felspar, and pegmatite. The pegmatites form rounded cores, and some of the quartz fragments are likewise rounded, while others are angular and even of rectangular shape. The very fine-grained veins not only contain quartz fragments similar to those in the body of the rock, but in many instances rectangular felspar fragments are so abundant as to monopolise the greater portion of the veins, which vary from an inch to a foot in width. In the narrowest of these the individual felspathic fragments occupy the entire breadth of the vein.

Mica trap occurs on both shores forming the entrance to Cowland and Lamouth Creeks, to the south of Halwyn. It is about 15 feet thick and is lying at a very low angle, while the exposure on the southern shore shows the sill as strictly conforming to the bedding of the Portscatho beds. They are characterised by numerous quartz inclusions, both angular and sub-angular, one of which is 8 or 9 inches in size. The band is visible at Higher Trelease following the same direction about a quarter of a mile further north. According to Mr. Collins mica trap also occurs in Cowland Creek, in a faulted condition, which he has figured.*

At Penpoll, west of Lambe Creek, a decomposing mica trap has a width of 6 or 8 yards. It is also seen on the shore below Penpoll Wood, forming a series of disconnected patches and lying nearly flat amongst highly disturbed Portscatho beds. It shares in the dislocations of the slate, and is in one instance divided by a slide plane containing slate along the line of fissure. Seeing, however, that the rock is intrusive, the slate seam may be in its natural position, and it thus served as a plane of weakness. On the opposite shore, at Victoria Point, Mr. Collins has figured† two mica trap dykes, 2 feet and 8 feet thick respectively, in close proximity, that share in an abrupt contortion of the killas. Unfortunately, at the time of the survey, these rocks were not visible on account of the muddy condition of the shore, so that we are unable to confirm Mr. Collins' description. A 2-foot sill, however, is seen in the immediate vicinity (170 yards N.N.W. of Victoria Point) in a quarry, conforming strictly to the bedding of the Portscatho strata, and showing no disturbance.

To the north-west of Truro these rocks are seen in the vicinity of Shortlane End, Gloweth, and Boscolleth. At the former locality they are marked by a line of pits on the farm of Carvinack, the buildings of which have largely been constructed of this stone.

At Gloweth a mica trap has been wrought, and an old quarry that formerly existed north of the road in the same locality doubtless marks a continuation of the same band. Two exposures

* *Journ. Roy. Inst. Corn.*, vol. viii., p. 195.
† *Op. cit.*, p. 196.

are seen nearly a quarter of a mile north of Boscolleth. Mr. Collins states* that this band is intersected at Treliske by an elvan. We were unable to discover its junction in the course of the survey, nor has another instance been recorded in the West of England of an intersection of a mica trap and elvan. Mr. Collins' statement, however, is important, as if he has correctly interpreted the nature of the intersection the relative ages of the mica traps and elvans are defined. It must be confessed that the fractured condition of the mica traps supports their greater antiquity, as already pointed out by us.† Their probable association, however, with the Permian volcanic rocks, and the Carboniferous age of the elvans have naturally led to the opinion that the mica traps are of later age; and until a section can be laid bare showing unequivocally the intersection of the two rocks the question is an open one. As Mr. Collins has not described the section showing their junction, we have no means of judging whether the evidence was sufficiently clear as to be absolutely decisive.

According to Mr. Collins, a mica trap showing spheroidal structure occurs in a quarry at Ashfield, between Falmouth and Penryn‡, and another occurs at Penryn.§

There are doubtless other bands that have been exposed which we have been unable to trace, through the infilling of the pits from which the material was formerly raised, either as stone, or for manurial purposes.

* *Journ. Roy. Inst. Corn.*, vol. viii., pp. 197 and 202.

† *Trans. Roy. Geol. Soc. Cornwall*, vol. xii., part vii., 1901. On the plutonic and other igneous rocks of West Cornwall, by J. B. Hill.

‡ *Journ. Roy. Inst. Corn.*, vol. viii., p. 193. This quarry is at present overgrown and largely inaccessible.

§ At the back of Messrs. Fox's timber yard. We were unable to inspect the section, as it was blocked by timber. Mr. Howard Fox described the rock and noted its spheroidal structure in a paper read before the Miners' Association of Cornwall in 1873.

CHAPTER VII.

CONTACT METAMORPHISM EFFECTED BY THE GRANITE.

The granite masses of Carnmenellis, Carn Brea, and Carn Marth are in such close proximity that their metamorphic aureoles overlap. It will be convenient, therefore, to describe their contact alteration on the surrounding killas without reference to these individual masses, but rather to regard the granite as a unit. Moreover, as already remarked, it has been demonstrated that the granites of Carnmenellis and Carn Brea are connected beneath the surface. The killas into which it has been intruded is confined to one division, viz., the Mylor series, and where it flanks the granite has been considerably altered by contact action, so that we have an encircling metamorphic aureole, the width of which exhibits great variation.

While the extent of the aureole depends on the subterranean contour of the granite, the degree of metamorphism, notwithstanding a general decrease from the granite margin outwards, is by no means uniform. While this is to some extent connected with the diverse chemical composition of the killas, it cannot be doubted that the structural features must likewise contribute to this result. The sediments were folded, fractured, and cleaved prior to the irruption of the granite. Moreover, the compression to which they owe their deformation has taken place at depths sufficiently shallow to lie well within the zone of fracture. Consequently, the folds are rarely of great amplitude, as relief from strain has been readily afforded by actual disruption. In some instances plication is altogether absent, and fault planes have been directly produced unaccompanied by folding. More frequently, however, plication and fracture accompany one another. As a result the rock mass is divided into a series of irregular segments that may be compared to a regional breccia. The fracture planes have but slight displacement and the continuity of the general dip is not seriously affected. This brecciation has in some cases been carried so far as to permeate the interstitial portion of the rock mass, so that crush breccias and pseudo-conglomerates have been extensively developed. As the ultimate result of these mechanical changes the killas is on the large scale singularly incohesive. The intrusion of the granite, in spite of the concomitant disturbances necessitated by its injection, has to some extent restored the solidity of the killas; the contact alteration to which it has been subjected being comparable to a process of rock welding, so that within the metamorphic aureole the beds are more massive than beyond it. The heterogeneous nature of the killas due to these structural changes alone, doubtless played an important part in controlling the chemical changes set up during the cooling of the granite. Not only must the

rock have exhibited great variation as a conductor of heat, but the unequal cohesion would have affected the outward passage of the thermal currents.

The varying widths of the contact aureole have been already described in Chapter I. in connection with the hade at which the granite plunges beneath the surface. The differentiation of the various degrees of mineral alteration within the aureole is in this area unfortunately impossible. A study, moreover, of a series of specimens taken at progressive distances from the granite margin, leads to the conclusion that such zonal division could not have been accomplished if all difficulties in connection with the obscurity of the sections were removed.

Throughout the contact zone the dominant feature is the development of spots or knots forming "spotted slates" or *knotenschiefer*, which are especially marked in the argillaceous members of the killas. This peculiar aggregation of material that characterises the earlier stages of thermal metamorphism is, so far as the outer portion of the aureole is concerned, the sole product of alteration. It is, however, also strongly developed among the more highly modified products of the inner zone.

As the rocks are mainly argillaceous, the contact minerals formed are chiefly aluminous silicates, the most characteristic of which are andalusite, muscovite, and biotite. These minerals occupy the inner zone. Andalusite is distributed for a distance of about 150 yards from the granite. Secondary white mica and biotite are especially conspicuous in the inner zone, the biotite perhaps occupying a wider range than the muscovite. Both micas, however, closely aggregated, occur generally in very tiny scales, the biotite being of the characteristic reddish brown colour of the contact type. In some areas hornfels has been produced in which the spotted structure is absent. Pyroxene and garnet have only been exceptionally noted in the contact zone, and usually in association with the greenstones. The knots exhibit various forms; they are sometimes aggregations of carbonaceous matter, in others they represent andalusite in an imperfect state of crystallisation, while again they may be aggregates of mica and quartz. Tourmaline is occasionally present, but in this area it is not often a common mineral in the contact zone. It has been already remarked that the killas is frequently divided by shear planes that impart the mechanical structure of a schist. Consequently, in the inner zone of alteration mica schists have been developed, the crystallisation of which has been the result of contact metamorphism.

Microscopic Characters of the Metamorphic Zone.—A description, however, of some of the micro-slides will better illustrate the phenomena of the contact zone. At Tregarne Mill, a specimen taken from close to the junction of the killas with the granite is an andalusite slate, with large crystals of colourless andalusite, which is only rarely pleochroic, in a matrix of biotite and quartz (3,385). A specimen about 80 yards distant from the granite margin, near Penryn, is a knotted andalusite slate, showing an advanced stage of contact alteration. The mass of the

slate consists of biotite, muscovite, and quartz, and these form winding, irregular, sinuous, interrupted folia. There are large paler knots, consisting principally of quartz and biotite, and others which are mainly muscovite and biotite. Many large crystals of andalusite are scattered through the rock; they are occasionally pleochroic, but are usually nearly colourless. The enclosures are biotite, magnetite, and dark matter, apparently graphitic, and as they are sometimes arranged to form a rude cross the mineral approaches chiastolite. The folia curve around and never pass through them (3,434). About 100 yards from the granite junction, at Treviades, a knotted andalusite slate is composed principally of quartz, biotite, and muscovite. The quartz forms strongly-marked parallel bands running along the foliation. The biotite is deep brown, and is partly weathered into chlorite and limonite. Andalusite is abundant, although the crystals are not large, but tend rather to form aggregates of small grains. In this rock knotting is neither conspicuous in the hand specimen nor in the slide (3,435). At Penwarne, at a distance of 120 yards from the granite, the rock is essentially similar. It is roughly foliated and rather nodular, but the knotted character is not very pronounced (3,436).

At Polwheveral, about 135 yards from the granite, a specimen shows on its surface pale, divergent, sheaf-like masses, resembling those of the *garbenschiefer*. Under the microscope (3,437) it consists of biotite, muscovite, quartz, andalusite with a small amount of tourmaline, magnetite, and chlorite. The andalusite is often full of biotite, but never resembles chiastolite in the arrangement of its enclosures. The foliation of the rock is rude and imperfect.

Specimens obtained at greater distances from the granite, where the rock is more in the condition of typical spotted slate, were also examined under the microscope by Dr. Flett. One obtained at Roscarrack, about 500 yards from the granite, is a sheared decomposed killas, that is contact altered. It consists principally of pale muscovite and quartz, with spots of clustered biotite. There is a little tourmaline, but no andalusite. The rock is a good deal sheared, and fractures pass through it in curved branching lines that are well defined by a deposit of limonite. The contact alteration is principally displayed in this rock by the spotting (3,438).

A specimen from the outer margin of the aureole, about 900 yards from the granite junction, is a grey slate much spotted on the surface (3,439).

In Penryn Creek the aureole of metamorphism suddenly diverts to the eastward, forming a narrow loop extending as far as Flushing. Whether this feature, whereby the contact zone is locally enlarged to the width of a mile and three-quarters, is the result of unevenness in the subterranean contour of the granite, or to crustal movements, is not apparent. On the coast below Trevissome, in Penryn Creek, a specimen of a silky slate or phyllite, that is knotted, is seen under the microscope to be crushed, and crossed by quartz veins that are distinctly granu-

litic in character, and are broken and interrupted. Lines of fracture cross the cleavage, and along them the laminæ of the rock are faulted, forming a sort of *ausweichungsclivage.* The knots are obscure, being filled with limonite, and largely composed of mica (3,576). A little further up the creek, about a quarter of a mile south-east of St. Gluvias Church, the rock is a fine shale with prominent quartz veins. Under the microscope it consists of small plates of mica mixed with fine angular quartz. There are a few rounded knots containing small crystals of biotite and quartz (3,577).

At Treluswell, within 300 yards of the granite, a pyroxene hornfels occurs. The sections here are very obscure, but greenstone is probably in close proximity. The shale, therefore, had probably been modified by the latter before the granite intrusion. The rock is crumpled with dark wavy lines, suggesting that it was originally an argillaceous sediment, but it is very rich in clear, shapeless crystals of colourless pyroxene, which are developed in rounded patches and along certain belts. The intervening matrix is a fine mosaic of quartz, and perhaps felspar, filled with dark opaque granules. Although having the appearance of an altered calcareous shale it is probable that the lime has been derived from the adjacent greenstone (3,380).

At Ponsanooth, on the eastern side of the stream, the Mylor series is very siliceous, containing very fine-grained quartzose bands, some of which are 4 feet in thickness. A specimen selected from the latter about 100 yards from the granite junction was determined under the microscope to be a contact-altered sheared grit. It consists of a mosaic of quartz grains, which have largely lost their rounded clastic form as the result of hornfelsing. A reddish brown biotite forms wavy streaks and irregular clusters, and is apparently a product of contact alteration. Zircon, iron ores, and garnet are the principal accessories (3,447).

A contact-altered shale from the same district and equally distant from the granite, one-eighth of a mile east of Cosawes, shows under the microscope the lamination and slate structure well preserved. There is no knotting, but the specimen is crossed with veins of granular quartz. The rock consists of small angular quartz grains, with biotite and muscovite. The biotite is dark brown, quite fresh and very abundant, and its parallel scales impart to the rock a distinctly schistose appearance. In the hand specimen it resembles an indurated hornfels (3,578).

In the district of Redruth a very coarse type of andalusite hornfels was noticed amongst the mine burrows, about 170 yards west of Grambler. The andalusite occurs in needles, nearly half an inch in length, and somewhat pink in colour in the hand specimen. Under the microscope (3,861) it is often colourless, or shows a dichroism from colourless to pale pink. The remainder of the slide consists of muscovite, biotite, and quartz, with a few grains of brown tourmaline. The rock is an andalusite biotite

hornfels, in a highly crystalline condition, that has been much decomposed.

In the south-west portion of the map the actual junction of the granite and killas is seen in the railway cutting, one-sixth of a mile south by west of Trannack. Under the microscope the Mylor slate is seen to consist of alternating layers of grit and shale, much altered by contact metamorphism. The gritty bands are changed into a mosaic of quartz grains filled with small scales of chlorite and brown biotite, while the argillaceous layers are represented by chlorite and muscovite, with iron ores, and occasionally a little biotite. The chlorite has probably all resulted from the decomposition of the original biotite, so that the rock is a decomposed biotite hornfels. The contact structures in the grit bands are well developed, but andalusite was not found in the slide (3,951).

A hornfels occurring in the railway cutting 100 yards south-east of Praze Station is likewise of the chloritic type. The biotite is replaced by chlorite, and it contains also muscovite, quartz, iron oxides, together with a little tourmaline in small brown prisms, and the rock is indistinctly spotted (3,952).

To the west of Crowan the aureole of metamorphism reaches beyond Clowance to the western edge of the map, near Penhale Moor. According to Mr. Dixon, the altered belt extends thence to the north coast and connects this aureole with the metamorphic region north of Gwinear. The outer limit of the sporadic spotting has been traced by Mr. Dixon to Illogan, from which it extends to Porth Towan on one side and to Crane Islands on the other; and he remarks that some of the spots are rhombohedral, and composed of carbonates.

Mr. J. Arthur Phillips, in his description of the rocks of the mining districts of Cornwall,* gives two chemical analyses from the metamorphic aureole of this area, as follows:—

Water	hygrometric	·48	·94
	combined	·67	2·18
Silica		67·32	67·82
Phosphoric anhydride		—	—
Titanic anhydride		·13	—
Alumina anhydride		20·85	9·56
Ferrous oxide		1·66	5·02
Ferric oxide		2·83	trace
Ferric persulphide		—	·68
Manganous oxide		—	1·20
Lime		2·03	2·58
Magnesia		trace	3·42
Potash		·60	2·37
Soda		3·37	4·32
		99·94	100·09
Specific gravity		2·71	2·73

* *Q.J.G.S.*, vol. xxxi., 1875, p. 322.

The analysis in the first column was taken from killas in the 215-fathom level of the Dolcoath Mine, while the other refers to a specimen taken from Huel Seton, Camborne, at the 160-fathom level. From the author's description the latter has apparently been more metamorphosed than the former. It will be noted that although the percentage of silica in the two rocks is almost identical, there is a marked reduction of alumina in the latter, together with an excess of iron and potassium, while manganese and magnesia are present in appreciable quantities. Mr. Phillips remarks that the amount of magnesia in the rock bounding the great cross course at Huel Seton, "which is traversed by the modified sea-water constituting the well-known lithia spring, is twice as large as in the normal killas of the locality. The magnesium of the sea-water has in this case almost entirely disappeared."

Mr. J. H. Collins has described some contact-altered killas from Penryn as gneiss. The Mylor slates there, in the vicinity of the granite, have been highly metamorphosed and may be accurately designated as mica schists. Mr. Collins made an analysis, as follows* :—

Combined water	·90
Silica	76·85
Alumina	15·05
Ferric oxide	0·50
Ferrous oxide	1·80
Lime	0·10
Magnesia	0·10
Potash	1·39
Soda	2·33
Loss	0·98
	100·00
Specific gravity	2·587

A specimen was examined by Professor Judd, who detected the presence of minute garnets. Although portions of the altered killas may contain transitional stages between mica schist and gneiss, the rock as a whole does not approach the latter category.†

* *Journ. Roy. Inst. Corn.*, vol. viii., p. 82.

† The occurrence of gneiss at Penryn was contested by Mr. A. Somervail. *Journ. Roy. Inst. Corn.*, vol. vii. p. 264.

CHAPTER VIII.

FAULTS.

In Chapter III., dealing with the structure of the killas, it has been pointed out that the Palæozoic earth movements which preceded the granite intrusions resulted in a system of rock flexure and fracture that were directly related. Under the influence of compression the crust was broken up into rock segments so closely aggregated as to present on a large scale the character of a regional breccia. These pre-granitic fractures are individually of slight displacement, and their profusion is such that they cannot be delineated on a small scale map.

The rock deformation in mass, which not only effected that regional breccia but evolved pseudo-conglomerates on a large scale, was brought to a close by the granite intrusions towards the close of the Carboniferous period. That volcanic phase was accompanied by a system of rock fracture parallel to the belt of intrusions represented both by granite and elvan. These fractures have a trend of about E.N.E., and agreeing with the main trend of the sediments they form strike faults which are not readily detected. Many of them, however, occur in the mineral areas, where they form the home of the lodes. Although their average trend is E.N.E. many follow directions oblique to that course.

There is another set of faults with a N.N.W. direction that are of later age, and not only cut the E.N.E. group but also the elvans, and their transverse course both to these and to the normal strike of the sediments renders them more conspicuous than the former group of faults. Many of them are known to the miner as cross courses, some of which heave the E.N.E. lodes, a description of which is given in Chapter XV. These faults are especially prominent along the belt occupied by the Carnon Valley, and extending to the north coast on the one hand, and to Restronguet Creek on the other. This system of fracture has originated since the formation of the tin and copper lodes, and their close parallelism with the fissuring produced by the volcanic eruptions of early Tertiary times render it extremely probable that they should be referred to that period.

Although these two prominent types of dislocation are the products of the later Carboniferous and the early Tertiary periods respectively, it is not implied that fractures can be rigidly assigned from their directions alone to those two phases of dislocation. Doubtless, fissures following either trend have been produced over the extended period that has elapsed since Carboniferous times.

CHAPTER IX.

PLIOCENE DEPOSITS.

POLCREBO GRAVELS.

A deposit of quartz gravel at Blue Pool, in Crowan, has been described by Mr. W. Tyack.* As it occurs at an elevation of about 500 feet, and as remarked by Mr. Tyack does not appear to have any connection with the alluvia of the district, there are some grounds for the opinion that it represents a patch of the Pliocene deposits that formerly spread over the killas platform of this area, and the only other representatives of which are found at St. Erth, St. Agnes, and Crousa Downs, in the adjacent maps.

The deposit occurs on a common near Polcrebo, in the heart of the granite district. Mr. Tyack describes the bed as consisting of quartz pebbles, evidently akin to the spar of the district, and varying both in structure and colour. They are more waterworn than the stream deposits of the Cober River, but in his opinion have been subjected to less attrition than the pebbles in the marine beaches at Loe Bar and Perranuthnoe. "They are of all sizes, from boulders as large as a pumpkin to pebbles as small as hazel-nuts; the larger ones are few in number and generally found most deeply bedded in the soft clay on which the greater part of the pebbles lie; they are also the smoothest. The small ones are most numerous, and are generally on, or very near, the surface. Most of the pebbles are about the size of a hen's egg; the very small ones are but slightly more waterworn than those of any river-bed pebbles in the district."

The deposit occupies an area less than half a mile in length and about a quarter of a mile in breadth, and thins away towards the margin. Mr. Tyack also states that it overlies a substratum of clay, derived from the decomposition of the granite, in which some of the larger pebbles have sunk to various depths; the subsoil being soft and saturated with water in the winter months. The gravel has been worked for tin, but it was never rich. Similar pebbles are seen about a mile distant in the valley below, at an old abandoned stream-work, at Velanhausen, but whether they were carted, or brought down by the stream, is uncertain.

Mr. Tyack was of opinion that the pebbles were derived from quartz veins in a killas district, but drew attention to the fact that they occurred at a greater elevation than the killas in their vicinity; and that, moreover, they could not have reached their position by stream deposit in the present surface configuration of the area. He attributed their origin, nevertheless, to an ancient river the traces of which have been removed by a vast amount of

* *Trans. Roy. Geol. Soc. Corn.*, vol. ix., pp. 177—181.

denudation that has obliterated all traces of the valley in which the river flowed.

According to that observer, the few granite fragments with which the quartz pebbles are mixed are rough and angular, so that we may conclude that they were not embedded in the original gravel deposit, but represent detached fragments from the underlying granite. Mr. Tyack was evidently of the same opinion, as he lays such great stress on the deposit having originated in a killas area.

As we are unable to conceive of a river whose volume permitted of the transportation and attrition of the large boulders described flowing over a bedrock of granite, without the incorporation of that material in its alluvia, the origin of these Polcrebo gravels must be sought elsewhere.

As the deposit accords approximately in elevation with the old Pliocene shore-line, it is probably a relic of the marine accumulations that lined the floor of the Pliocene sea; and Mr. Clement Reid, who has recently examined the deposit, agrees with this opinion.* The association of gravel and bedrock, sharply contrasted in their lithology, may be readily accounted for by the shore deposits being swept forward by the currents to such portions of the rocky bottom as were beyond the destructive action of the breakers.

* See also remarks by C. Reid, in "Summary of Progress" for 1901, p. 31.

CHAPTER X.

PLEISTOCENE DEPOSITS.

I. Raised Beaches.

With the exception of the Polcrebo gravels, this area affords no evidence of stratified deposits from the Palæozoic period until the Pleistocene, the latter being represented by the raised beaches underlying the Head, which is probably a product of the glacial age.

These ancient beaches* that were laid down in the Pleistocene seas, form ledges which fringe the coast seldom more than a few feet above the present sea level. The raised beaches, composed of material identical with that of their modern counterparts, are sometimes cemented by oxide of iron that has consolidated them into a condition of durability. In this state they offer great resistance to wave action, as is well seen in Gerrans Bay on the beach of Pendower. In some instances the ancient caves of the Pleistocene coast have been partially preserved by the old beach floor being sufficiently consolidated to form the roof of modern caverns that have been excavated in a lower portion of the same cleft, examples of which are seen in Falmouth Bay.

Even on the coast-line, where beaches are absent, a tiny fringe of gravel is often visible. It may be observed along some of the steeper cliffs, where its preservation is obviously due to the durability of the cementing material, which has not only held the particles together, but has firmly bound the gravel to the rock on which it rests.

Every gradation is seen between well-defined beaches and mere shreds of gravel, either cemented or incoherent, that occur in isolated strips above the present high-water mark, the degradation of which causes the commingling on the modern beach of the Pleistocene pebbles with those of recent origin. The beaches of either age contain, in addition to fragmental material representing the detritus of the adjacent rock formations, numerous foreign pebbles, mainly chalk flints and cherts, which in some situations are profusely distributed. They have either been swept around the coast by current action, or have been derived from a deposit more ancient than the raised beach which may fringe the coast beneath the level of the sea.†

In some instances the recent rock shelf, planed by wave action, has been shaped from the more ancient Pleistocene platform. This is well seen at Sunny Cove, in Falmouth Bay, where the older platform, standing but 5 or 6 feet above the present eroded

* These raised beaches were described by local geologists prior to the survey by De la Beche. See also W. A. E. Ussher on "The Recent Geology of Cornwall" (articles reprinted from the *Geol. Mag.*), 1879; and "The Post-Tertiary Geology of Cornwall" (printed for private circulation), 1879.

† The latter explanation is supported by the occurrence of a gravel deposit, largely composed of flint and chert, in St. Martin's Island, that is probably of Eocene age. See page 15, "Geology of the Isles of Scilly" (*Mem. Geol. Survey*), by George Barrow.

shelf, is fringed along the coastal notch by the innermost edges of the raised beach, averaging but a foot or so in thickness, that has escaped destruction. (Plate VIII.) Notwithstanding the close juxtaposition of these Pleistocene and Recent formations, the interval which separates them has been marked by considerable vertical oscillations of the coast-line, the evidence of which will be given later. The final results of such crustal movements have been that the relative level of land and sea more closely approximates to the old Pleistocene coast-line than in the periods that have intervened. The appearance of the ancient ledges along the present cliff faces would at first suggest that the coastal erosion due to wave action had been slight since Pleistocene times, but the explanation is to be found in the oscillations of level that have taken place in the interval, so that the erosion of the modern coastal shelf has been restricted to the period that has succeeded the submergence of the forest beds.

Between Gerrans Bay and the Zoze Point there are three examples of the Pleistocene beach, one of which occurs at Pendower, along the north front of Gerrans Bay; another lines the inner portion of the small bay at Portscatho; while the last is similarly situated in the bay fronting Towan beach. The raised beach of Pendower is a magnificent example, and owes its preservation to a very thick deposit of Head, which has acted as a protective covering. It is resting on a killas floor, a very few feet above the level of high-water mark: the base consists of coarse fragments of slate and quartz with which pebbly beds of the same nature are mixed, while the upper portions consist of red and brown sandstone and sand, bound together by a cementing material of oxide of iron. It sometimes attains a thickness of 8 to 10 feet, but is often much less, and the deposit is not always continuous. This beach has been described and figured with its relations to the underlying rocky base and the overlying Head by Mr. Howard Fox.* At Portscatho it is represented by an insignificant shelf of gravel and rusty sand that follows the coastal shelf below the Head, a little above high-water mark. At Towan beach, however, there is a more extensive exposure of Head, and the underlying beach is consequently well preserved. On the southern edge of the deposit there is a thickness of about 15 feet of Head that overlies about 2 or 3 feet of sand and gravel, some of which is compacted by iron oxide, as at Pendower, while in other parts it is a friable deposit of gravel and sand. Continued further north, the beach deposit, as at Pendower, is seen to be discontinuous, and in some places appears to be represented by a gravelly clay. The raised beach here, together with the overlying Head, has been trenched by a small channel connecting Towan beach with Porth Creek, the seaward portion of which has been covered by a deposit of blown sand.

In Falmouth Bay† the raised beach is also seen in a corre-

* *Trans. Royal Geol. Soc. Cornwall*, 1896, p. 9.

† In 1832, R. W. Fox drew attention to the raised beaches of Falmouth Bay. *Phil. Mag.*, vol. i., December, 1832, p. 471.

sponding position at the base of the Head, between Swan Pool and the Falmouth Hotel. It consists of gravel, partly cemented, in which quartz is usually the chief constituent, and its base stands a very few feet above high-water mark. A little to the north of Pennance Point there is a small deposit of Head, from 20 to 25 feet in thickness, beneath which there is a layer of compact stratified sand from 1½ feet to 2 feet in depth, the shelf being only three or four feet above high-water mark.

Between Pennance Point and Maen Porth a deposit of Head lines the coast in the neighbourhood of Sunny Cove, and rests on a rock shelf a few feet above high-water mark; moreover, as remarked earlier, this platform stands about five or six feet above another which marks the modern shore-line. In Sunny Cove the ancient beach, about three or four feet in thickness, is dissected by the cleft which forms the cove, and consists of gravel, often stained yellow, and even black, and frequently very compact, while angular blocks of slate are also enclosed, especially towards its base. Between Newporth Head and Maen Porth a small portion of the old beach is adhering to the cliff face at a height of from twelve to fifteen feet above high-water mark.

Traces of this raised beach are also seen along the coast of the Carrick Roads and the harbours of St. Mawes and Falmouth. In St. Mawes Harbour, on the coast north-east of Carricknath Point, a deposit of white quartz gravel, well rounded, and about a foot in thickness, is overlain by Head. The gravel contains also some blocks of slate, while some of the quartz pebbles are six inches in length. The deposit is only three or four feet above high-water mark, and appears to be slightly distorted from the creep of the overlying Head.

Between Castle Point (St. Mawes) and St. Just the coast is lined more or less continuously with a narrow ledge of Head, at the base of which there is a deposit of quartz gravel about a foot in thickness. A little to the south of St. Just the raised beach, about a foot thick, consists of sand and gravel; the band is not horizontal, but slightly undulating. In the upper part of the Carrick Roads it has not been observed, although the Head is sometimes present. North of a line drawn between Mylor and St. Just the only example is on the coast to the south of Weir Point, where a bed of quartz fragments about a foot thick is seen below a thin covering of Head. Between Penarrow Point and Trefusis Point the deposit, however, is almost continuous at the base of the Head. It averages about a foot in thickness, and consists of white quartz gravel, usually incohesive, but sometimes cemented firmly together. It is often very coarse, with blocks up to six inches in size that are more or less rounded, but at times angular. On the north side of Falmouth Harbour, notwithstanding an extensive deposit of Head that fringes the coast, the raised beach is almost entirely absent; a small ledge, however, underlies the Head, to the east of Wheal Clinton.

Traces of the platform are met with in the cliffs and islets along the north coast, while at Portreath and Kerriack Cove

patches of the Pleistocene shingle are found firmly cemented to it by manganese dioxide.

II. Head.

This deposit forms an irregular accumulation, in which stony material preponderates, often reaching great depths on the coast, and overlying the raised beaches and the killas. The Head is sometimes almost identical with the subsoil, into which it frequently merges. In fact, this abnormal deposit may be looked upon largely as subsoil that has been transported to lower levels. It is sometimes stratified, and may even contain beds of sand and fairly rounded gravel; more often, however, it presents an irregular accumulation of stones, mostly angular, and occasionally subangular.

This formation is probably of glacial age. While nowhere on the mainland of Cornwall* is there evidence of glacial action, its proximity to the icefield that lay to the north necessarily entailed the rigours of an Arctic climate, under which the land was incapable of supporting any but the sparsest vegetation. The melting of the winter snows and the ice which bound the frozen soil, acting on a surface unchecked by vegetation, probably involved the sweeping of material down the slopes that would amply account for the abnormal nature of the deposit. In its downward course it has filled the hollows on the coast-line, and covered the shelf of the ancient beach, to which it has afforded a protection, so that the thickest deposits of Head are found in the smaller bays, by the infilling of which the shore-line has been modified. Some writers have considered the Head to have been formed beneath the sea, but the phenomena which it presents can be more satisfactorily accounted for on the above hypothesis.

The Head which covers the raised beach at Pendower in Gerrans Bay forms a cliff from 20 to 50 feet in height. Mr. Howard Fox described it as "composed of loam and sand, and containing occasional angular fragments of quartz, chert, and shale."† This deposit also extends from Pendower to Creek Stephen Point; and about a quarter of a mile before reaching the latter locality it is fully a hundred feet deep; this section contains also some sandy material. At Creek Stephen Point, where it is only fifteen feet thick, the basal portion consists of stratified brown sand. As the upper surface merges into the hill slope, its inland limits can rarely be ascertained, but the strip is usually very narrow. Another shelf skirts the cliff between Portscatho and Porthcurnick, and overlies the raised beach, but that coast-

* In 1843 Sir R. I. Murchison, in his address to the Geological Society of London, expressed the opinion that the search in Cornwall for the evidence of ancient glaciers would be unsuccessful. The principal exponent of the theory of glacial action in Cornwall has been Mr. Nicholas Whitley. We have failed, however, to detect any indications of glacial phenomena, although some blocks herein described are of the nature of erratics that have slid to lower levels over a frozen surface. In the Scilly Isles Mr. Barrow has recently described a glacial deposit, with ice-scratched stones, that overlies the Head, and which is attributed to the action of ice-floes. See pp. 21-28, "Geology of the Isles of Scilly" (*Mem. Geol. Survey*).

† *Trans. Roy. Geol. Soc. Corn.*, 1896, p. 9.

line is rapidly receding, from the effect of landslips: south of Pencabe the section is about twenty feet thick. Another extensive deposit forms a cliff fronting Towan beach, and is in part sandy and rudely stratified: towards the north its upper part consists of sandy material and fine gravel mixed with soil for a depth of a foot or eighteen inches. The cliff at Falmouth fronting the bay affords a good section of Head overlying the raised beach, where it is frequently sandy and stratified. A thick deposit also reposes on the raised beach at Sunny Cove.

Within the Falmouth estuary ledges of Head frequently line the coast. Opposite St. Mawes a deposit of this nature overlies the raised beach north-west of Carricknath Point. Between St. Mawes Point and St. Just Pool a similar ledge is almost continuously exposed, occasionally from 15 to 20 feet in thickness, and frequently underlain by the ancient beach. On the coast, rather more than half a mile south of Messack Point, the Head is from 8 to 10 feet in depth, rudely stratified, and capped by a thin layer of loose gravel. On the north side of the Carrick Roads a deposit lines the coast from Pill to within a short distance of Restronguet Point. Between the entrances to Restronguet Creek and Mylor Creek are two smaller patches; one, south of Weir Point, is about 4 or 5 feet in depth, and rests on the raised beach; the other, south of Great Wood, is 12 feet thick, and reposes directly on the rock platform of the modern shore. From Penarrow Point to Flushing it forms a well-marked ledge, sloping to the coast, and underlain almost continuously by the raised beach. Another conspicuous deposit of this type fronts the shore of Pendennis Peninsula from Middle Point to the Docks, where it has been quarried: the pit section exhibits at the base fine sand that is overlain by about 12 feet of more typical Head, which, however, is stratified; the slate fragments, instead of being irregularly disposed, lie with their flat sides parallel with the dip, which is towards the sea. Although this is a well-marked ledge, the landward boundary cannot be accurately drawn, as it merges gradually into the hill slope.*

In the valleys and estuaries which converge to the Carrick Roads, deposits of Head are less frequent. There is, moreover, in the interior a difficulty in distinguishing it from the subsoil, especially where the latter is of great thickness. Some of the inland accumulations, however, which are in the nature of drift, may have been formed contemporaneously and under the same general conditions. In the district of Bissoe, for instance, between Wheal Baddon and Wheal Clifford, the slopes are covered with débris for a depth of several feet. In the vicinity of Pennance, below Carn Marth, the slopes are strewn with granite detritus far below the granite margin. Moreover, the size of some of the blocks and the general nature of the ground preclude the possibility of the phenomena being due to the downward creep of the surface débris under the conditions that prevail at the

* A characteristic of the Head that reposes on the Pleistocene platform is its smooth surface, which from a distance recalls the features of the Raised Beaches of the West of Scotland. This is especially noticeable within the Falmouth estuary. (See Plate II.)

present day. A more striking instance still of the transport of material from a distance is seen on the northern flank of the Carn Brea granite. A section along the railway cutting, between Carn Brea Mine and Barncoose, exposes a deposit of granite detritus, several feet in thickness, resting upon killas. In the finer material blocks of granite are incorporated, some of which attain a size of 5 or 6 feet. The granite margin is probably about 70 yards distant at the west end of the section, and about 180 yards at the eastern portion. If the ground were steep, this deposit at such a short distance from the granite would not be unusual, but as a matter of fact the land here is comparatively flat, the angle of slope being only from 1° to 2° while the declivity from the base of Carn Brea hill extending to a distance of 500 yards only averages 4°. It is clear, therefore, that the larger granite blocks could only have reached their present situation under abnormal conditions, and in all probability they were detached from the summit of Carn Brea while its slopes were covered with frozen snow, over which they slid to their present position.

III. Stream Tin and Submerged Valley Deposits.

Stream Tin.—The stream tin industry in Cornwall is now a matter of the past, the valleys and basins in which these deposits occurred having been repeatedly worked over, and their sites now remain as tumbled and disordered ground, much of which from an agricultural standpoint is a waste. While we are unfortunately precluded from the examination of these deposits in their natural condition, they present interesting questions of post-Tertiary geology that cannot be overlooked. As will be seen later, at Restronguet Creek, where the section is below the level of the sea, the stream tin deposit immediately overlies the rock shelf. This relative position of the rocky floor and stream tin, according to all accounts, holds good wherever these deposits have been worked. As observed by De la Beche,* while the submerged stream tin deposits were being covered by marine or estuarine accumulations, "the stanniferous gravel strewed down the higher parts of the valleys became simply covered by ordinary river alluvium, mingled with trees and vegetable matter; in flat places, such as may have constituted marshy ground or shallow lakes, peat accumulating intermingled with the waste of gravels, sands, and clays, from the adjoining higher lands, in the same manner as now takes place commonly in peat-countries."

The peculiar association of the stream tin with the subjacent rock, instead of being interstratified with the alluvial deposits, was ascribed by the earlier geologists to the effects of a sweeping denudation having passed over the land, and in the words of Mr. Carne,† "the effects produced by which have never been repeated by any subsequent flood." Moreover, the fact that the more extensive deposits of stream tin occurred in the valleys that opened to the south, notwithstanding that the richer tin veins were situated in the northern region, was considered to indicate that

* "Report on the Geology of Cornwall, Devon, and West Somerset," p. 406.
†. *Trans. Roy. Geol. Soc. Cornwall*, vol. iv., p. 55.

the current of the deluge* swept from the north.† This theory was apparently countenanced by De la Beche, who suggested that a great body of water crossing the Bristol Channel from South Wales carried forward the disintegrated material of the rocks that opposed it on this side of the Channel, "transporting them into the chief inequalities, and carrying them down the principal valleys, according to the directions of the minor currents produced by the inequalities of the land beneath."‡

Although we have failed to detect evidence of glaciation in this part of Cornwall, it is known that glaciers reached the Bristol Channel, and its proximity to the Welsh icefield must have entailed an Arctic climate during the period of maximum glaciation. Not only does the highly decomposed condition of the surface rocks discountenance the idea of glacial action, but further confirmation is afforded by the absence of rock striæ, and erratics from the north.

As already premised, in treating of the origin of the Head, in glacial times the ground must have been covered with snow, and it is probable that the more elevated tracts lay permanently above the snow-line. The melting of the winter snows and the ice that bound the frozen soil must have been productive of floods that swept the valley floors with a volume and velocity altogether incomparable with the insignificant and sluggish streams that water the valleys at the present day. Under such conditions, it can be readily understood that only the denser detrital matter could find a resting place along their channels. No doubt previous to this period the bottoms of the valleys were not bare, but assuming that they were lined with alluvia no thicker than that which obtains at present, its removal by such torrential floods would be a simple process. It is unnecessary to assume that the occurrence of stream tin adjacent to the bedrock, without occupying higher positions between the overlying alluvia, implies a simple and continuous sequence of deposit with the heavier material at the base. In all probability the intervals between the periodical floods were marked by the deposition of normal alluvia. With the renewal, however, of torrential conditions, these lighter deposits would be swept away, just as we suppose the alluvia that originally lined the valley floor was dispersed. No doubt these periodical scourings of the river basins succeeded in carrying to the sea much of the stream tin itself. At the close of this period, when the severity of its climatal conditions had passed away, the deposit of stream tin lying on the bedrock was the sole relic of a long period of deposition, extending not only over the era which evolved such deposit, but over the period which preceded it. To put the case succinctly, the conditions which permitted of the formation of the stream tin involved the destruction of normal alluvial deposits, both older and contemporaneous.

The explanation suggested herein to account for the phenomena

* *Trans. Geol. Soc. Cornwall*, vol. iv., p. 55.
† *Ibid.* p. 110.
‡ Report previously cited, p. 401.

presented by the stream tin supports the theories advanced by the earlier observers, to the extent that both hypotheses invoke torrential conditions. Whilst their view of a general diluvial immersion and the advance of a large body of water from north to south cannot be sustained, yet the facts on which it is based are substantially correct, although admitting of a simpler interpretation. That, so far as this area is concerned, the stream tin was principally located in the valleys opening on the south coast, and that the more important tin lodes lie in the northern tracts, may be admitted. These phenomena, however, appear to be in harmony with the physical features of the district. The watershed is not only nearer to the north coast, but the rivers which drain that area are shorter, and therefore of greater declivity; consequently, more of the stream tin proportionately reached the sea. Now the rivers emptying on the south are not only of lower gradient but traverse a larger area, and also more frequently become confluent, so that their lower portions have received the deposits brought down by numerous tributaries. This is illustrated by the river which discharges into Restronguet Creek, and contains the celebrated tin stream works of Carnon. This river system attains a total length of about 45 miles, 25 miles of which are situated in the metalliferous districts of Chacewater, Scorrier, St. Day, Gwennap, Baldhu, and Bissoe. Although it is true that the individual lodes of this central area are not so rich as those situated in the northern tract of Camborne and Redruth, yet the amount of stanniferous detritus spread over the surface and susceptible of denudation may quite well have equalled or even exceeded the tin-bearing detritus of the northern area, in spite of greater mineral concentration in the latter. Moreover, when it is considered that the stream tin of the northern region has been distributed by numerous rivers, whereas the drainage system of the district which culminates in the Carnon Valley converges to a single channel, the more extensive alluvial deposits of the latter are readily accounted for.

Submerged Valley Deposits.—The submergence of the land which the forest beds imply is further supported by the evidence of the deposits that will now be described. The search for stream tin has been the means of dissecting these accumulations at Restronguet below the level of the sea, where remains of a forest growth in its natural position are buried beneath deposits exceeding 50 feet in thickness that overlie the stream tin. The following is a section of the Carnon stream-works by Mr. Henwood* :—

	ft.	in.
1. Sand and mud ; the river wash - - - - -	3	0
2. Silt and shells—three successive beds - - - -	0	10
3. Sand and shells - - - - - - - - -	2	0
4. Silt—three beds - - - - - - - - -	12	0
5. Sand and shells - - - - - - - - -	3 to 4	0
6. Silt mixed with shells in large quantities - - -	12	0
7. Silt, in some places containing stones - - - -	18 to 22	0

* *Trans. Roy. Geol. Soc. Cornwall*, vol. iv., p. 58.

	ft.	in.
8. Wood, moss, leaves, nuts, &c., all of a dark colour, much resembling what has been charred; a few oyster shells; animal remains, those of the deer being most abundant; and some human skulls - - - - - - -	1	6
Towards the sea the bed 8 entirely disappears, giving place to 7, which reposes on		
9. The tin-ground, which consists of rounded masses of tin-ore, in some cases unmixed with any other substance, in others in a matrix of quartz, and quartz and schorl, with rounded pieces of slate, granite, and quartz, varying in thickness from a few inches to - - - - - -	12	0

The following section was supplied by Edward Smith in 1807.* As pointed out by De la Beche, the name "Carnon Streams" has been given to a long line of works down the valley, so that the section is subject to variations:—

	ft.
1. Mud and sand - - - - - - - - -	7
2. Granite gravel, intermingled with small pieces of a substance resembling charcoal, and a few shells - - - -	4
3. Fine gravel, mud, and shells - - - - - -	12
About this depth are several irregular strata of oysters, about 4 or 5 feet in thickness, extending irregularly to within 4 or 5 feet of the tin ground.	
4. Closer mud, intermingled with shells - - - - -	19
In this stratum have been found several branches and trunks of trees, some of which had evident marks of being cut with an axe or other sharp instrument; antlers and bones of stags, likewise human skulls.	
5. Tin-ground, varying from - - - - - - - - -	1 to 2

De la Beche states that the shells from these sections which he had examined, corresponded with the species still found in the Falmouth estuary.†

At the time when De la Beche wrote, the higher Carnon Works had been "abandoned, the search for stream tin in the same valley being confined to the bottom of Restronguet Creek, beneath the tidal waters of the estuary, on the south of Daniell's Point."‡ These submarine operations, however, have long since ceased. Beyond the area of the present sheet a very similar section has been described at Pentuan, where human skulls are stated to have been found 40 feet below the surface, mingled with the remains of deer, oxen, hogs, and whales. Assuming these facts to be correct, then, as De la Beche remarks, "a considerable change took place in the relative levels of sea and land since man inhabited Cornwall, allowing estuary or marine deposits to be effected in creeks upon a surface that previously permitted the growth of terrestrial vegetation, the remains of the marine creatures entombed in the mud, silt, or sand showing that these creatures were of the same species as those which now exist in the adjoining sea."§

As these submerged valley deposits have only been brought to light by the search for tin, their occurrence can only in these instances be demonstrated. It cannot be doubted, however, that similar evidence exists in other valleys which extend seaward as tidal estuaries.

* *Trans. Geol. Soc.*, vol. iv., 1817, p. 404.
† Report previously cited, p. 404.
‡ Report previously cited, pp. 404 and 405.
§ "Report on Cornwall, Devon, and West Somerset," p. 407.

CHAPTER XI.

RECENT DEPOSITS.

I. SUBMERGED FORESTS.

While the raised beaches demonstrate the elevation of the coast-line, the presence of forest beds beneath the level of the sea point just as clearly to its subsidence. The existence of the submarine forest fronting the valley at Maen Porth has long been known. It can, however, rarely be observed, being buried beneath sand and shingle. Portions of it are, nevertheless, occasionally laid bare after heavy gales, during the lowest tides. It has been described by the Rev. Canon Rogers,* who observed the stump of an oak in its position of growth, with peaty material enclosing its roots, and containing the remains of the common yellow flag (*Iris pseudo-corus*) still flourishing in the adjoining swamp. In 1895, after a succession of easterly gales, the overlying shingle was removed, and part of this submarine forest was exposed. It was described by Mr. S. Roberts,† who found the jawbone of a small horse that has been doubtfully referred to an extinct species. On the same occasion an antler of a deer was obtained by a workman.‡ The mould was excavated to a depth of 3 feet by Mr. Roberts without reaching the bottom. It emitted a noxious odour of sulphuretted hydrogen, and contained the "remains of aquatic plants, the impress of the leaves, stems, rootlets, and flags being very marked. Hazel-nut shells, hazel twig with the bark on, as well as fir cones partially deprived of their seeds, were abundant. These were so compacted together that, when removed, their prints were well-defined in the mould." The mould contained a number of trees lying in various positions, some of them from 12 to 20 feet in length, the largest reaching a diameter of 2 feet, and all yielded readily to the touch. Mr. Roberts states that some of the timber was nearly black, and some of a reddish colour, and considered that it was represented by oak, pine, alder, willow and hazel. The jawbone was found close to a large prostrate tree trunk. "It was about 1 foot in length, and set in it in perfect order were five large teeth—the whole set—all molars, well preserved with labyrinthine crowns."

In 1871 a submarine forest was laid bare at Market Strand, Falmouth, and described by Mr. H. M. Whitley.§ The forest bed was about 7 feet thick, and its surface about the level of low-water mark, and buried beneath a bed of sand about 2 feet in thickness, while it was separated from the underlying rock by about 4 feet of gravel. It consisted of compact peat containing the remains of flags, ferns, and trees, few of which exceeded 12 inches in diameter,

* *Trs. R.G.S. Corn.*, vol. iv., p. 481.

† *Trs. R.G.S. Corn.*, vol. xii., part ii., p. 58.

‡ Both the antler and the jawbone are in the possession of Mr. Robert Fox, of Grove Hill, Falmouth.

§ *Journ. Roy. Inst. Corn.*, 1872, No. 13, p. 77.

chiefly of hazel, oak, and fir, but beech and birch were also abundant. The forest bed is continuous for some distance inland along the valley known as the Moor,* while another portion of the forest was exposed during excavations at the Bar pools.

In Gerrans Bay a submerged forest was observed some years ago at Porthcurnick by Mr. H. G. Handsombody, who saw tree stumps projecting from the sand at low tide. In 1898 we observed a large root at Pendower beach that had evidently been detached from the forest bed at the mouth of the valley at Pendower, which was seen quite recently by Mr. Clement Reid.

At Portreath, on the north coast, peat was encountered beneath the sand in a dock excavation.

While the beginning of the submergence in which these forest beds are involved may have followed closely on the termination of the glacial period, there are some grounds for the opinion that it may have continued to historic times.

II. Marine Alluvia.

Numerous beaches of sand and shingle have accumulated in the various bays along the seaboard, the most extensive of which on the south coast occur at Pendower, Porthcurnick, Towan, Falmouth, and Maen Porth. The beach at Swanpool that fronts the mouth of a valley, has acted as a natural dam and ponded back a considerable freshwater lake, while in other localities the free egress of the streams has been so far checked as to produce swamps at the valley mouths, as at Gyllyngvase and Maen Porth.

The deposits, however, that line the estuaries, and which are laid bare at low tide, are of far greater extent than the accumulations which have collected in the more sheltered situations along the seafront. The mud discharged by the streams into these estuaries is gradually filling them. At Restronguet, ships could ride at anchor considerably farther up the Creek than at present, within the memory of the present generation; while the mud-flats of the River Fal, below Ardevora, are creeping rapidly seaward at a rate that is readily detected. Tradition avers that Tregoney was an important Roman settlement accessible to shipping, and there is historic evidence that the tidal waters reached that place in the sixteenth century. The Fal estuary is of especial interest, as the tidal flats, instead of forming banks of dark mud derived from the decomposition of the killas, consist of pale tenacious clay, brought down from the surface of the western portion of the St. Austell granite mass. That rock, being in a highly decomposed condition, is eroded more rapidly than the killas, so that the material deposited in the estuary consists largely of impure kaolin from that district, considerably augmented by the drainage of the waste water from the china clay works.

An instructive paper on the silting up of the creeks of Falmouth Haven was communicated by Mr. H. M. Whitley in 1881 to the Royal Institution of Cornwall.† The comparison between

* The lower part of this valley was formerly the site of a tidal inlet that has since been artificially reclaimed.

† *Journ.*, vol. vii., pp. 12—17; also pp. 50—52.

the ancient and modern charts affords conclusive evidence of the serious nature of the shoaling, and to some extent of the rate at which the mud banks are accumulating. Between the years 1698 and 1855 the bottom has risen 12 feet at Tolvern Point, and 18 feet at Tregothnan boathouse.

The most extensive silting appears to have taken place in Devoran Creek, being considerably augmented there by the mining operations along the Carnon Valley. Mr. Richard Thomas, in his history of Falmouth, states that the channel opposite Penpoll has silted up 10 feet since the Admiralty survey of 1698, and at Restronguet Pool, at the higher end, where in 1698 there was a depth of 42 feet at low water, was in 1855 dry at the same period, and at the lower end there was a growth of 12 feet in the same interval; whilst the bank between the main channel of the Haven and Restronguet "has shoaled during the same period from 12 to 3 feet at low water." Although the creeks are shoaling more rapidly than the main harbour, Mr. Thomas calculated that the silt brought down into the harbour would form a layer 1 foot thick in about 43 years, supposing it uniformly distributed throughout the haven and its branches.

III. Freshwater Alluvia.

Notwithstanding the extensive valley system that prevails over the area, the alluvial deposits that line its floors are comparatively meagre, while the streams that water them are proportionately insignificant.

Age of the Valleys.—From what has been already said, it will be understood that these deposits have been laid down since the stream tin, even in those localities where the latter is absent, for it is evident that the cleaning out of the valleys was universal over the district. The evidence, moreover, of the submarine valley section at Restronguet, shows that these deposits which overlie the stream tin belong to the Recent period. While the age of the valleys cannot be demonstrated, they may probably be referred to the later Pliocene period. Subsequent to the emergence of the Pliocene sea floor, more ancient valleys, however, may have been sealed beneath Pliocene deposits, the evidence of which has been lost by the removal of the material that filled them. That the valleys were enlarged in the Pleistocene epoch is very evident, as the raised beach which lines the coast of the lower portion of the Carrick Roads is not met with in the estuaries that diverge from that inlet. Moreover, the deposits of Head along the valleys and estuaries are insignificant. We may conclude, therefore, that both deposits were removed by the torrential conditions attending the formation of the stream tin. Notwithstanding their great depth, some of the valleys have very narrow floors, probably due to their being deepened rapidly in the glacial epoch, when they must have presented the appearance of narrow gorges.

Nature of the Alluvia.—The alluvium of the killas districts consists of a muddy silt in which sand and gravel deposits are rare, except where the higher portions of the streams have traversed

granite areas, when detritus from that rock has been brought down in the form of gravel, the grains of which are unrounded. In granite districts the alluvia is mainly of the latter description. In some situations, where the declivity is slight, clay has been formed, more especially in the upland basins. River terraces, marking different stages of deposit, are rare: moreover, the alluvial flat itself, which lines the valley floor, occasionally presents difficulties in its demarcation. Not only does it often merge insensibly into the débris of the valley slopes, but the streams frequently originate in broad, open basins, and the tracing of the alluvia along these hollows is attended with much uncertainty. This is especially the case in granite areas, as the débris formed by the decomposition of this rock is practically indistinguishable from the granitic alluvia. In valleys that have been worked for stream tin, or which have been used for treatment of the ores raised from the mines, the alluvial margins have often been obliterated, and along some of the hollows the ground is so disordered that it is uncertain to what extent they were lined with alluvia. The stream tin valley of Porkellis, in the parish of Wendron, may be instanced as an example. Moreover, this valley is fringed by gentle slopes, in which the underlying granite is completely hidden by a soil cap made up of its débris, and corresponding precisely with the granite alluvia which floors the valley, and the one shades imperceptibly into the other. The uplands occupied by the granite present numerous instances of alluvial basins in which the original flat is gradually being modified by the soil creep from the slopes. Some of the moors which so frequently occur at the heads of the valleys have thus been formed. The want of fall renders drainage difficult, and their clay bottoms are frequently lined with marshes.

THE VALLEY SYSTEMS.—The valleys are disposed in three prevalent directions that are common to the whole district, but each type predominates in certain areas. On the eastern portion of the sheet the principal valleys trend from north-east to north-north-east. On the horizon of Truro and Falmouth there is a strong tendency for the larger hollows to run north and south, while west of that belt the majority of the streams lie in valleys trending from north-west to north-north-west. The north and south system is in all probability the oldest, as it appears to have no relation to the structural features of the geological formations which make up the existing land surface. The north-north-east system approximates to the general strike of the killas and to the system of fracture produced by the volcanic disturbances of the newer Palæozoic period; while the north-north-west system coincides with the direction of fracture that probably originated in early Tertiary times. To what extent the valleys coincide with faults there is seldom evidence to show, but the straightness of some of them, and in other cases their parallelism, suggests that their course has frequently been determined by lines of dislocation or well-marked joints. Moreover, two valleys divided by a ridge are often in perfect alignment as if their course had been determined by a single line of fissure.

RATE OF GROWTH OF THE ALLUVIAL DEPOSITS.—The Fal is the largest river within the region, but only its lower reaches enter this area. As that part of the river was, however, in historic times, a tidal estuary, the age of the alluvium can be approximately ascertained. In the description of the marine alluvia the seaward growth of the valleys and their encroachment on the tidal estuaries is referred to. There is evidence to show that the alluvial flat above Lamorran and Ruan Lanihorne has been formed since the sixteenth century, and Mr. H. M. Whitley has estimated that it has been silted up at the rate of 1 foot in about thirty years.*

The deposits lining the Carnon Valley have been still more rapidly accumulated, mainly as the result of the extensive mining operations that formerly prevailed. In 1620 the tide flowed beyond Lower Carnon, and, according to tradition, it even once flowed above Bissoe Bridge.† It has been calculated that at the height of mining activity—in the 21 years between 1821 and 1842—deposition was at the rate of 1 foot in five years. According to the late Mr. W. J. Henwood,‡ the surface of the valley at Higher Carnon was raised between the years 1820 and 1867 at the rate of about 1 foot in ten years.

IV. BLOWN SAND.

Sand dunes and towans are seldom developed in this area. These æolian deposits are mainly composed of finely comminuted sea shells, such as form the shelly beaches, and have been largely utilised in Cornwall for enriching the soil by the lime contained in their composition. On the north coast there is an extensive development of blown sand at Porth Towan, from which the name has evidently been derived. On the south coast sand dunes occur at Pendower and at the mouth of the hollow a quarter of a mile east-south-east of Gwendra. At Porthcurnick blown sand occurs, but not to any appreciable extent. Further south, in the parish of St. Anthony, a tract of blown sand fronts Towan beach below Porth Farm, and has succeeded in choking an old channel connecting the estuary with the open sea that formerly constituted the present peninsula of St. Anthony an island.

* *Journal Roy. Inst. Cornwall,* vol. vii., p. 12.
† About 1⅝ miles above the point now reached by ordinary tides.
‡ Presidential Address, Roy. Inst. Cornwall, 1870.

CHAPTER XII.

ECONOMIC RESOURCES, EXCLUDING THE ORES.*

SOILS AND VEGETATION.—The fertility of the district is subject to great variation. While the larger part of the area yields a generous soil susceptible of a high degree of cultivation, there are large tracts occupied by gorse and heath that are comparatively barren. Not only do these fluctuations depend on the character of the underlying rock, but an important influence has been exercised by physical situation. Among the latter, such conditions as elevation, proximity to the north or south coast, the shelter afforded by valleys, and the varying declivities of the slopes have materially contributed. The geological conditions are very pronounced in areas occupied by granite as compared with districts characterised by killas. There is a further marked distinction in the metalliferous areas and the districts that bound them; in much of the former the mineral alteration and excess of quartz has materially impoverished the soil, while in some cases the extensive mining operations and stream washings have devastated large tracts that would otherwise have been susceptible of cultivation.

The eastern area is very fertile and is given over entirely to agriculture. The district lying within the basin of the Fal and its extensive tributary system is in a high state of cultivation, and includes the parishes of Probus, St. Erme, St. Clement, Kenwyn, Kea, Feock, Merther, Lamorran, Cornelly, St. Michael-Penkevil, Ruan Lanihorne, and Philleigh. The peninsula south of Philleigh, embracing the parishes of St. Just, Gerrans, and St. Anthony, is almost equally fertile. West of the Carrick Roads and Falmouth Bay, the tract extending inland as far as the granite produces good agricultural land in the parishes of Mylor, Penryn, Falmouth, and Budock.

The killas which enters into the geology of the eastern area is mainly confined to the Portscatho division, but the Falmouth and Mylor groups are also represented. There is no very marked difference in the lithological types of these divisions, so that the soils resulting from their disintegration present no striking contrasts. On the whole, perhaps, the Falmouth group furnishes the best soil, especially when represented by the sandy friable type that so readily decomposes. This is well illustrated by the rich lands of Ardevora, in the parish of Ruan Lanihorne. In the area occupied by the Portscatho group it has been observed that the soil is lighter and of a higher agricultural value where the sandy types prevail.

The extensive valley system, into which the eastern area has been trenched, has produced marked variations in the agricultural

* Mining economics are treated in Part II.

value of the land. In some parts of the region the valleys are so closely adjacent that the intervening ground affords little or no flat land. In fact, it may be claimed generally that in this area level ground is almost entirely restricted to the valley floors, and that the difference between one tract and another is that characterised by the relative declivities of their slopes: some valleys being broad and open, while others are narrow and steep. In the former the soil is deep, while in the latter the covering is so thin that the rock often protrudes at the surface. The wash of the soil from steep slopes to their base is counteracted by the farmer, who periodically respreads it on the higher land to preserve its fertility.

The great mineral area between Camborne and Baldhu consists largely of killas. The extensive mining operations have laid waste large tracts, especially in the districts between Baldhu and Scorrier. Besides this cause, the soil is often materially impoverished by the large amount of quartz detritus, derived from the disintegration of the siliceous veins. Apart, however, from these considerations, the belt of country fringing the north coast, and in which mineralisation is not conspicuous, is markedly less fertile than the killas on the south, and there are large tracts which are out of cultivation.* These northern slopes not only suffer from their bleaker aspect, but the district is not so extensively trenched by valleys as the south, and is consequently more exposed to the winds. This is particularly brought out by the comparative absence of woodland in the northern district, whereas the southern tract sustains flourishing plantations, and exotics from warmer climes thrive in its gardens.

The killas area on the extreme western portion of the sheet, between Camborne and Carnmeal Downs, is fertile and almost entirely under cultivation, while the timber at Clowance flourishes in a degree altogether unusual in the district, comparing favourably with the woods of the Fal basin.

The granite district exhibits marked variations in its agricultural value. While over large tracts the rock is buried beneath a soil cap through which it rarely protrudes, these areas are often suddenly replaced by rocky wastes that are sterile, while in other situations good arable land is broken by extensive protrusions of rock. Whereas the differences in elevation over the granite areas partly accounts for these variations, this cause does not altogether explain the phenomena. Fertile tracts and barren areas are frequently closely adjacent, and although resulting doubtless from chemical distinctions in the granite that have affected the nature of its decomposition, these mineralogical variations in the field are not always to be detected.

The Carnmenellis granite reaches a height of 819 feet. Its northern margin has an average elevation of about 500 feet, while the eastern portion descends to the 300-ft. level and sometimes

* Much of the Downs has been reclaimed comparatively recently, thick dressings of "marl" being applied, the material of which has been mainly derived from greenstone.

lower. The western portion is higher than the eastern, and succeeds the killas between 300 and 400 feet above sea level. The most fertile areas are the eastern and southern slopes in the parishes of Stithians, St. Gluvias, Budock, Mabe, and Constantine. On the other hand the most elevated region at Carnmenellis, and including Nine Maidens, Calvadnack and from thence to Cannebone, is the most barren part of the tract, little of which is under cultivation, the remainder consisting of rocky wastes covered with gorse and heath. The land also lying between East Wheal Lovell and Wendron is an abandoned mining district, the agricultural value of which is poor. The whole of the western region of Crowan, and including Polcrebo, contains large tracts of uncultivated downs. On the north, about Carwynnen, there is also a large area out of cultivation.

As already remarked, there is a great discordance in the depth of the granitic soils apart from differences in elevation. In some districts the granite is decomposed for a considerable depth from the surface, as is seen in the neighbourhood of Rame Common, and extending to Menerdue on the north and to Butteriss Downs on the south. While in this district the granite disintegrates to a friable soil which is light to work, it frequently yields a stiff clay. Indeed, over the granite area generally, the soil is cold as compared to the killas, and crops are later. Although some portions of the granite region include lands that are highly productive, the killas areas are the most fertile, irrespective of the factor of their being more low lying. This is exemplified on the granite margin, where there are sharp differences in fertility at its junction with the killas, the area occupied by the latter being markedly superior.

The summit of Carn Brea reaches an elevation of 740 feet in the granite region named after that peak. This rugged country is replaced near Bosleake by cultivated lands that occupy the remainder of the granite area in its course to the south-west, the continuity of which is occasionally broken by rock as at Carn Arthen, and further west at The Rocks, near Croft Danger.

The Carn Marth granite area is mainly under cultivation, except in the southern and most elevated tract, culminating in its summit at an elevation of 771 feet.

The decomposition of the greenstones yields a rich soil, but these rocks occupy an insignificant portion of the area.

The mica traps, while still more sparsely distributed, disintegrate readier and possess a manurial value from the phosphoric acid which they contain.

THE STONE INDUSTRY.—This area furnishes a large proportion of the granite that forms the well-known Cornish granite industry, the rock being mainly raised from the Carnmenellis mass.

The headquarters of this industry is situated at Penryn, where the stone is dressed, and from which port it is shipped. The granite raised, however, in the more southern districts of Mabe and Constantine is shipped at Porthnavis. The stone is mainly wrought in a belt of country lying to the west of Penryn, extending from the south of Stithians to Long Downs and Burnthouse,

Eathorne, and Brill. In this tract quarries are both numerous and extensive. Beyond this region granite is wrought along the Cober Valley, south-west of Wendron, and at Carwynnen, about two miles south of Camborne. Besides these localities, quarries on a smaller scale, many of which are no longer working, occur on the eastern margin of the Carnmenellis granite near Pencoose, at Kennal Vale, Ponsanooth, Penryn, Budock, and Penwarne. In the western area the principal localities where the stone has been raised are at Croft Michell, Praze, Crowan, Bognio, Nancegollan, and Prospidnick. Quarries have been worked also at Lower Tretharrup, near Carrannel, Tretheague, Halabezack, Tolcarne, and at other localities which need not be enumerated.

The granite is grey in colour, and its principal mineral constituents are felspar, quartz, and two micas, viz., muscovite and biotite, while tourmaline is commonly present as an accessory mineral. In texture there are two varieties, known commercially as "fine grit" and "coarse grit." The former, which usually occupies the outer belt for an average width of about a mile, although the superior stone, is not so extensively worked as the "coarse grit," on account of its being more expensive to dress. It is not only finer in texture, but is darker in colour, containing more biotite, and has a higher specific gravity (about 1 per cent.). A good example of this stone is seen at the quarries at Carnsew, about one mile west of Penryn. The "coarse grit" is a more attractive stone, and is studded with porphyritic felspars that reach an inch or more in size, some of the most beautiful varieties of which occur in the parish of Mabe.

As remarked in a former chapter, the granite is divided by a threefold set of joint planes, one of which is horizontal and the others vertical, the latter intersecting one another approximately at right angles. Moreover, the joints are sufficiently far apart to admit of the extraction of immense blocks. In fact, the favourable disposition of the jointing is one of the most important factors in contributing to the success of the Cornish granite industry. (Plate IX.)

The principal quarries are confined to the eastern portion of the Carnmenellis mass, where the rock is little disturbed, and in which elvans are rare. In the central and north-western area the granite has been subject to much fissuring and disturbance, in connection with the oncoming of the mineral veins, and in these districts the stone has only been raised for local purposes. Not only so, but the rock is frequently less uniform from the abundance of finer-grained granite and aplite veins with which the normal rock is mixed. These differences in texture cause irregularities in the joint planes, which renders its working unprofitable.

Even in the granite belt which forms the heart of the industry these veins are of too frequent occurrence, and are often the cause of the quarry being abandoned.

These finer-grained granites or aplites are rarely, however, sufficiently large to be independently quarried, and in some instances they are not easily distinguished from the elvans. In

fact, the term elvan as used by the quarrymen includes these finer varieties. A quarry of this nature occurs at Lower Tretharrup, near Lanner.

The Carn Brea granite is of similar texture to that of Carnmenellis, and has been raised in various places between Carn Brea and Carn Arthen. At Bosleake a quarry has been opened on one of the finer-grained veins.

The Carn Marth granite is of somewhat similar texture to the "fine grit" stone of the Carnmenellis granite, but the felspars are usually porphyritic, and of a slender habit. It is quarried extensively on the hill of Carn Marth. It is frequently, however, mixed with veins, and is inferior commercially to the granite of Mabe and Constantine. It has supplied the principal building stone of the town of Redruth.

The following table, for which we are indebted to Messrs. John Freeman & Co., Penryn, illustrates the crushing strength of the Carnmenellis granite, as determined by Mr. David Kircaldy in May, 1904 :—

Locality.	Dimensions.		Base Area.	Crushed.		
				Stress.	per sq. in.	per sq. ft.
		Inches.	sq. ins.	lbs.	lbs.	tons.
Tresahoe (Parish of Constantine)	3·92	3·96 × 3·95	15·64	314,200	20,090	1,292·0
	4·00	3·98 × 3·97	15·80	335,700	21,247	1,366·4
	3·98	3·98 × 3·98	15·84	269,500	17,014	1,094·1
		Mean	15·76	306,467	19,450	1,250·8
Carnsew (Parish of Mabe)	3·96	3·96 × 3·96	15·68	398,500	25,415	1,634·4
	3·96	3·96 × 3·96	15·68	357,400	22,793	1,465·8
	3·97	3·96 × 3·96	15·68	294,800	18,801	1,209·1
		Mean	15·68	350,233	22,336	1,436·4

At the present time the granite industry is undergoing a period of depression consequent on its inability to compete with Norway, where the conditions of labour, the ease with which the rock is dressed, and its presence on the seaboard, facilitate its importation at a cost below that at which the stone can be remuneratively wrought in this country. The decline of the industry is being severely felt in the district of Penryn, whence some of the skilled workmen are emigrating to America.*

* Some idea of the extent of the granite trade in this part of Cornwall during recent years may be gathered from a perusal of the following table, which represents the supply of dressed stones by Messrs. J. Freeman & Co. or dock and harbour works, bridges, and lighthouse alone :—

The elvans afford some of the best building stones of the district, and have been extensively utilised. The harder varieties are extremely durable, but in many instances those in which a certain amount of decomposition has set in have been selected on account of the freedom with which they are dressed, and to which the term freestone has often been applied. Of this type are the elvans of Newham,† near Truro, at Porkellis, near Wendron, at Kerling Downs, near Chacewater, and many others.

These rocks have been so extensively quarried that it is unnecessary to enumerate the localities. The stone now being raised for building purposes to the south of Nine Maidens is of excellent quality, coarse in texture, and grey to pinkish in colour, and studded with dark nests of tourmaline. The well-known elvan at Saveock Water, to the east of Chacewater, is a somewhat similar stone, in which the tourmaline nests are exceptionally well developed. At Enys a fine-textured grey dyke has been quarried, which is exceedingly fresh. The stone wrought at Towntanna, and at Trevales, is often of a reddish colour. A very fine-grained light grey elvan is quarried at Tresevern Croft, and at Calvadnack; while a similar rock is wrought adjoining the high road to the north of Crelly, and between Little Trewince and Tregolls. The elvan that is worked at Greenwith and Pencoose is porphyritic, with a fine grey matrix; at the former locality it is fresh, but at Pencoose incipient decomposition has set in. At Lower Carnon another large dyke has been extensively quarried. The elvan at Kea, near Truro, is greyish green in colour, and is beginning to decompose. At Nansavallan, near Truro, a band is wrought of the porphyritic type. Near Redruth a dyke is quarried at Higher Cardew, and on the east of Carn Brea Castle a coarse-grained stone is being worked. On the northern flanks of Carn Brea a fine-textured grey elvan has

* DOCK AND HARBOUR WORKS.

	Total Order. *Cubic Feet.*	Supplied by Messrs. Freeman. *Cubic Feet.*
Gibraltar, 1899 to 1904	1,250,000	900,000
Keyham, 1897 to 1905	1,891,400	945,000
Cardiff, 1899 to 1904	142,000	142,000
Portsmouth, 1894 to 1896	606,000	606,000
Folkestone, 1897 to 1904	142,000	142,000
Dover Harbour Board, 1892 to 1901	118,162	118,162
Barry, 1892 to 1898	162,218	162,218

BRIDGES.

Kew, 1899 to 1902	149,000
Rutherglen, 1893 to 1895	90,643
Tower Bridge, 1887 to 1889	139,000

LIGHTHOUSE.

Fastnet, 1898 to 1902	69,000

† Mr. Collins states that a large portion of the city of Truro was built from this stone. *Trans. Roy. Geol. Soc. Cornwall*, vol. ix., p. 226.

been quarried. Good stone is also being raised from the quarries at Bolenowe Crofts and Bolenowe Moor, to the east of Troon. The dyke which runs through Gregwartha is fine-grained, soft and locally known as freestone; it is at present being quarried half a mile to the north-east of that locality. A hard durable stone is raised at Creegbrose, near Chacewater. At Praze Station there is a large quarry of a greyish green elvan of a very fine-grained, even texture, and a somewhat similar rock is wrought near Trevoole.

The greenstones and mica traps have only been exceptionally used for building purposes, the former on account of their toughness and cost of working, and the latter from their decomposition. In spite, however, of their general unsuitability, the mica traps have occasionally been utilised in preference to the killas amongst which they occur. When not too decomposed they are readily dressed, and are said to be durable. The greenstone has been quarried at Flushing, Bissom, Treluswell, Devis, Tuckingmill, and Wheal Trannack. At Camborne it has been extensively used for walls, in which huge blocks have been laid.

Notwithstanding the superabundance of excellent building stone in the district, the more massive beds of the killas have been employed where superior stone is not immediately available. Although situated within two miles of the Carnmenellis granite, the town of Falmouth is mainly built of killas, and that stone, especially the crush conglomerate, is still largely utilised for building material.

ROAD METAL.—The stone mainly employed for road metal is elvan, the finer varieties of which produce an excellent surface. Greenstone is also made use of to some extent, but notwithstanding its excellence this rock is frequently exceedingly tough to break, as at Treluswell and Ponsanooth; nevertheless, at this latter locality it is at present being worked. Granite forms an inferior road metal, but is often used in the granite areas. The harder sandy beds in the killas, especially the siliceous grits of the Lower Devonian area, are likewise wrought. Veinstone from the mine heaps is occasionally utilised. Stone is also imported, as the Plymouth limestone, and hornblende schist from the Meneage peninsula. These are mainly used, however, in the eastern district, where igneous rocks are rare, and where the tidal estuaries have favoured water carriage. The hornblende schist produces a greasy surface, and is, therefore, not so suitable as the greenstone. One of the latter type, locally known as "blue elvan," is at present being worked at Porthoustock by Messrs. Freeman & Co., and yields an excellent road metal.*

CLAYS.—China clay, into which some of the Cornish granites decompose, is rare in this district. At Lower Kergilliack, however, near Penryn, the granite yields an inferior china stone, which is mixed with imported china stone from the St. Austell

* Samples of this rock submitted to attrition tests yield dust to the low percentage of 4·61. The specific gravity of the stone is 2·91.

district, and worked at Penryn. China clay works of small extent formerly existed in Porkellis Moor, in the parish of Wendron.

Near St. Day the decomposing granite is utilised for the manufacture of bricks, and the factory turns out over a million annually. The granite is decomposed for a depth of about 50 feet, and was formerly used for china clay, but was unable to compete with the superior clays of the St. Austell district. On account of the gritty nature of the clay the individual bricks are cut by hand. Those produced from this decomposing granite have smooth faces, but their edges are imperfect.

Some of the decomposed elvans have also been worked commercially for their clay products. Between Carharrack and Lanner clay pits have been formerly opened on an elvan for china clay and bricks. Similar dykes have also been worked as clay pits at Sparry Bottom, in the parish of Gwennap, at Carnon Downs, and at Wheal Baddon.

The upper part of the Fal estuary is lined with a deposit of grey clay brought down by the drainage of the china clay district of St. Austell. This clay, which is of a whitish and pale yellow-grey colour, is not only used at Trelonck for the manufacture of bricks, but works have also been established for the production of the coarser varieties of earthenware. The following analysis of this clay was made by Dr. Pollard* from a sample taken at the ford between Ruan Lanihorne and Lamorran :—

Air-dried Sample.

SiO_2	49·67	Cl	·37
TiO_2	·19	H_2O 105°	1·30
Al_2O_3	33·43	H_2O above 105° + Some organic matter	9·64
Fe_2O_3	1·92		
CaO	Trace		
MnO	Trace		100·57
MgO	·37	Less O for Cl	·17
K_2O	3·32		
Na_2O	·29		100·40
Li_2O	Trace		
SO_3	·07		

The chlorine and sulphuric acid are due to sea water. The soluble salts amounted to ·83 per cent., the sand + acid silicates to 24·7 per cent.

WATER SUPPLY.—The granite and killas, which almost entirely make up the geology of the area, both hold water. The experience of miners leads to the conclusion that the killas contains more water than the granite, which is doubtless due to the excess of fissuring and shattering in the slaty rocks. The granite, however, appears to furnish the largest springs, and it is from this source that the principal towns of the district, viz., Falmouth, Penryn, Redruth, and Camborne, draw their water supply. Truro, on the other hand, obtains its water from the killas in the vicinity. Although there is no lack of water in the slate, the absence of large springs is often a serious difficulty in dealing with the water supply of the smaller villages that are unable to bear the expense

* "Summary of Progress of Geological Survey" for 1899, p. 175.

connected with storage reservoirs. The average water level is, perhaps, about 40 fathoms, but this is subject to great fluctuation. At Wheal Vor, for instance, it varied as much as from 30 fathoms in winter to 45 fathoms in summer. The public water supply of St. Agnes and Mount Hawke is obtained from the adit of an old mine east of the latter locality.

SMELTING, ARSENIC, AND OCHRE WORKS.—Tin smelting works are in operation at Point in Restronguet Creek. Further up the valley, at Bissoe, are two arsenic factories, one, situated about a quarter of a mile west of Bissoe bridge, employed in 1902 about 8 men in addition to carters. The crude arsenic calcined at the mines is sent there for refinement. Ochre works exist in the same locality, which at the time of our survey in 1902 were said to have been in continuous operation for over 40 years. The oxide of iron carried in suspension, in the waters that discharge from the main adit into the Carnon stream, is caught in small pools, after which it is pulverized and washed. It is then dried into a fine brown ochre, in winter by fires, and in summer by the sun. The works are small, and there is no continuous market for the product.

PART II.

MINING.

BY

D. A. MacALISTER.

CHAPTER XIII.

GEOLOGY OF THE MINERAL AREA.

The rock formations, together with their tectonics, have been described by Mr. Hill in the preceding pages. The mineral lodes of this district are almost entirely confined to those divisions of the killas which have been assigned to the Lower Palæozoic system, and to the granite, which invaded the killas about the close of the Carboniferous period.

As the metalliferous minerals are very largely concentrated in the mutual marginal zone of the granite and killas, and as the lodes are frequently influenced by their association with igneous sheets and dykes, the following details in connection with the subterranean occurrence of granite, elvan, and greenstone will elucidate the underground geology of the metalliferous region, so far as mining operations have revealed it :—

Subterranean Features of the Granite.

In a geological map constructed by Richard Thomas and published about the year 1819, the Redruth (or Carn Marth) granite mass is shown by a sea level contour of its junction with the overlying killas to be continuous with the Carnmenellis mass.

The Carn Brea granite is connected with the Carnmenellis mass underground, a fact confirmed both by the subterranean dips of the granite and from information obtained from the mines. It is, moreover, of identical lithological character, as described in Part I. It is possible that the three masses of granite are connected, but this conclusion requires verification.

Note.—In the ensuing pages the following publications are so frequently referred to that for the sake of brevity the author's surname alone will be quoted in the footnotes :—W. J. Henwood, "On Metalliferous Deposits of Cornwall and Devon." *Tr. R. G. S. Corn.*, vol. v., 1843. Richard Thomas, "Report on a Survey of the Mining District from Chacewater to Camborne," 1819. De la Beche, "Geological Report of Cornwall, Devon, and West Somerset," 1839. Joseph Carne, "On the Veins of Cornwall." *Tr. R. G. S. Corn.*, 1822, vol. ii. Clement le Neve Foster, "On the Great Flat Lode." *Q. J. G. S.*, 1878, vol. xxxiv. John Garby, "On some Cornish Mineral Localities." *Tr. R. G. S. Corn.*, vol. vii., 1847.

Its petrological character and mode of occurrence, as already pointed out by Mr. Hill, suggests the Carn Marth mass to be an independent intrusion, but it may nevertheless be in juxtaposition below the surface with the adjacent granite of Carnmenellis.*

The following table gives the dips† of the junction of the granite and killas :—

Mine.	From Point.	In direction.	Angle with horizon (near surface).	Remarks.
Carn Brea Granite.				
		Deg.	Deg.	
Camborne Vean	South of Engine shaft	N. 50 W.	58	Becomes flatter in depth and is thrown up into a ridge
Dolcoath ...	South of Stray Park shaft	N. 20 W.	72	Ditto.
Ditto... ...	North of William's New shaft	N. 22 W.	40	Becomes steeper until it meets with Dolcoath Main lode at about 140 fathoms from surface, when it is thrown up into a ridge
Ditto... ...	On Caunter lode	W. 5 N.	72	—
Ditto... ...	On Main lode near Eastern shaft	W. 32 S.	23	Becomes steeper and then flattens
Cook's Kitchen	South of Dunkin's shaft	N. 37 W.	30	Gets flatter and is thrown up into a ridge
Carn Brea ...	Providence shaft	N. 11 W.	30	Ditto.
Ditto... ...	Near Tregajorran	N. 48 W.	30	—
Ditto... ...	Druid shaft (on east)	N	30	Ditto.
East Carn Brea	North slope of tongue of granite	N. 24 W.	34	—
Wheal Uny ...	Southern slope of tongue of granite	S. 24 E.	40 (approx).	Becomes flatter and continues into the Carnmenellis mass
North Wheal Frances	—	S. 30 E.	35	Becomes flatter and continues into the Carnmenellis granite
South Dolcoath	—	S. 42 E.	18	Ditto.
South Condurrow	Near King's shaft	S. 45 E.	17	Ditto.
South Tolcarne	Near Taylor's shaft	S.	10	Tending to become steeper in depth

* J. B. Hill. "Summary of Progress of the Geological Survey for 1903," p. 26.

† The angle of dip is measured from the horizontal.

Mine.	From Point.	In direction.	Angle with horizon (near surface).	Remarks.
Redruth (or Carn Marth) Granite.				
		Deg.	Deg.	
Pedn an Drea	East of Bragg's shaft	W. a few deg. N.	18	At 75 fathoms from surface it is vertical for 30 fathoms below Street shaft. Then dips 32 deg. in the same direction
Ditto... ...	South of Trevena's shaft	N. 15 (?) W.	23	—
Wheal Beauchamp	—	—	40 to 50[1]	—
Ting Tang ...	North of Roach's shaft	S. 40 E.	47[2]	—
West Poldice	—	E. 30 N.	30[3]	Same dip in Poldice
Treskerby ...	—	—	22[4]	—
Carnmenellis Granite.				
Tresavean Mine	—	E. 40 N.	36[5]	Below the 60-fathom level the junction of the granite and killas is irregular and almost perpendicular in some places
Wheal Beauchamp	—	N.E.	60[6]	—
Wheal Buller	Point near ...	N. 24 W.	58	—
Wheal Basset	South of Marriott's shaft	N.	57	Gets flatter and then steep again
Wheal Grenville	South of King's shaft	N. 45 E.	30	—

From the foregoing data it is possible to form an idea of the shape of the granite surface concealed by the overlying slates (see Fig. 2). The western portion of the northern margin of the Carn Brea granite dips

[1] Henwood, p. 71.

[2] Thomas. p. 10, gives the dip of the granite and killas junction from Wheal Damsel to Carharrack as 10 deg. and in a direction S.E. towards Ting Tang Mine as 18 deg. Henwood, p. 71, gives the dip from East Wheal Damsel eastwards as 14 deg. to 16 deg.; and at Ting Tang in a S.E. direction as 40 deg. to 45 deg.

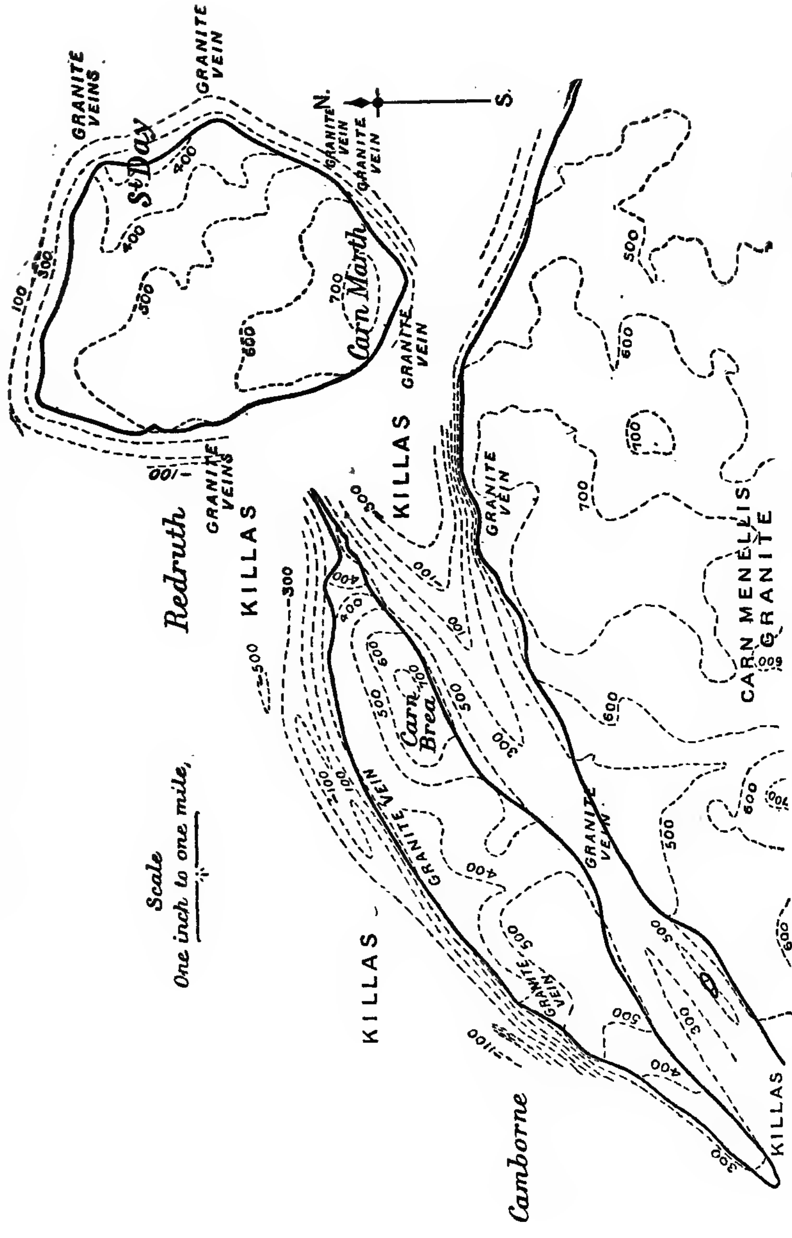
[3] *Op. cit.*, p. 10, gives dip at Wheal Gorland to Wheal Unity as 20 deg.

[4] *Op. cit.*, p. 10, gives dip as 26 deg.

[5] *Op. cit.*, p. 10. Henwood gives the dip as 40 deg., p. 71.

[6] Henwood, Table lviii.

FIG. 2.—*Subterranean Contour of the Granite.*



The thick lines show the margin of the granite as it appears on the Geological Map.
The dotted lines are contours at certain levels above and below sea level.

under the slates at a high angle (72 deg.); but in going eastwards it gradually flattens out, and in Cook's Kitchen Mine the dip is only 30 deg. Further east, near Redruth, it is inclined to the horizontal at 24 deg. The dip in the western portion of the southern margin is, at South Tolcarne Mine, only 10 deg., but in going eastwards the angle of dip increases until at North Wheal Frances it is 35 deg.; and further east still, in Wheal Uny, near Redruth, the angle is 40 deg. from the horizontal.

The elongate, somewhat curved shape of this mass is perhaps its most peculiar feature, as it is, correctly speaking, a ridge rather than a dome. On the east this peculiarity is strongly pronounced.

The Redruth (or Carn Marth) granite presents the form of a more even dome, since not only is the exposed surface more nearly circular, but the dips around its margin do not vary to such extent. The northern and western slopes dip beneath the killas at angles varying from 18 deg. to 23 deg. The eastern margin is steeper, and its slope beneath the killas varies from 30 deg. to 47 deg., the highest angle of dip being towards the south. The southern slope appears to have a maximum dip of about 50 deg.

The killas which lies in the subterranean basin formed by these three granite masses probably exceeds 1,200 feet in thickness in the vicinity of East Wheal Basset. Proceeding from thence westwards in a direction W. 35 deg. S., between the two granite hills (of the Carn Brea and Carnmenellis granites), the killas thins out rapidly, until at South Condurrow it is, at most, 300 feet in thickness, after which it dips away westwards at an unknown angle.

Underground exploration in the mines has to a certain extent revealed the character of the upper surface of the granite concealed by the killas. It appears to be undulating, but on the north of the Carn Brea mass there are two well-marked subterranean ridges[1] of granite striking in the same direction as the cleavage of the killas. The granite plunges northwards beneath the killas, and after reaching a certain depth it rises in the form of an irregular wave trending E. 30 deg. N. This subterranean ridge varies in height to a maximum of 40 fathoms, and has been identified in Camborne Vean Mine, Dolcoath, New Cook's Kitchen, Tincroft, and East Pool. About 150 fathoms further north there is a second but smaller ridge, of a maximum height of 30 fathoms, trending in the same direction, but only encountered in depth in South Crofty and East Pool.[2]

In this locality there are also a number of intrusive sheets protruding from the main mass of granite which penetrate the killas on the north of the Carn Brea granite. To the list of such intrusive offshoots encountered in mining operations, the particulars of which have been published,[3] may be added those which were met with in the adit level at Kellivose Mine,[4] and the tongue of granite which was driven through for several fathoms in Wheal Uny. At the 10-fathom level in Williams' shaft, in South Condurrow Mine, the junction of the granite and killas can be observed, where small veins of granite penetrate the killas. The 70-fathom cross-cut, in Wheal Basset, is driven northwards from the North Basset lode

[1] H. C. Salmon. *Mining and Smelting Magazine*, 1862, p. 385.

[2] There is difficulty in accurately tracing these ridges, and it may be that the former really trends from Camborne Vean, through Dolcoath, New Cook's Kitchen, and South Crofty to East Pool.

[3] W. Phillips, "On the Veins of Cornwall." *Tr. Geol. Soc.*, vol. ii., 1814, p. 152, and plate 7. Thomas; Henwood; Joseph Carne, "On the Veins of Cornwall." *Tr. R. G.S. Corn.*, vol. ii., 1822. Veins, tongues, or intrusive sheets of granite occurred in Kellivose, Dolcoath, Cook's Kitchen, Tincroft, Carn Brea, South Condurrow, Wheal Uny, Herland Mine, Wheal Basset, Pedn an Drea, East Wheal Sparnon, Wheal Beauchamp, Ting Tang, Wheal Damsel, Wheal Gorland, Poldice, Wheel Peevor, Cardrew Down Mine, Wheal Unity, Wheal Buller, Tresavean, Wheal Trannack, Carleen Mine, Wheal Vor.

[4] From an old report, Pendarves Estate Office, Camborne. Obtained through the courtesy of Mr. Vercoe.

towards South Carn Brea Mine and passes alternately, in some places, through granite and killas.

The deeper parts of the more important mines situated in the killas on the north of Carn Brea have reached the granite. In Wheal Agar the granite is encountered at a depth of from 140 to 150 fathoms. In East Pool it is about the 135-fathom level; in South Crofty it is met with at a depth of from 140 to 160 fathoms, but getting deeper westwards; in New Cook's Kitchen from 120 to 136 fathoms. In Wheal Tehidy, on the east, granite was not met with in the mine, but it is probably about 120 fathoms below surface. The granite was never reached in the Roskear or Seton Mines. Finally, in no case have the workings of any mine, when once fairly into the main mass of the granite, been known to pass through it.

Subterranean Occurrence of Elvan.[1]

Mining operations have revealed the presence of a greater number of elvans, both in the granite and killas, than can ever be discovered at surface; but the available information is scanty, owing to the fact that the miners have no interest in recording their occurrence, and consequently each discovery is soon forgotten. It is only in a few cases that all the particulars can be forthcoming, since it is only here and there that elvans are intersected during the development of the mine. This may partly account for the statement so commonly heard from miners that elvans occur in patches; but it is also certain that such intrusions are sometimes split up into branches.

At Wheal Beauchamp an elvan throws off several branches into the slates.[2] Several irregular "spots" of elvan occurred in the western part of Wheal Unity.[3] The elvans in the killas in Barncoose, Wheal Druid, and Wheal Basset are greatly branched.[4]

At Wheal Clifford the elvans are considerably branched in depth. Elvans sometimes show considerable change in width within short distances; thus at Wheal Beauchamp the elvan at the 29-fathom level is 3 fathoms in width, but at the 69 it is 30 fathoms in width.[5] In Wheal Unity an elvan varies in width from 6 feet to 60 fathoms.[6]

"The elvan courses are from two or three to twenty or thirty fathoms in breadth, some of them larger."[7] The following are a few selected examples of the widths of elvans as discovered in the mines:—In Wheal Beauchamp the width of the elvan is as much as 40 fathoms in some places.[8] In Wheal Buller an elvan is 25 fathoms in width.[9] In Consolidated Mines[10] there is an elvan 16 to 20 fathoms in width. In Cook's Kitchen an elvan is 17 fathoms wide;[11] another is 20 feet wide.[12] In Chacewater Mine an elvan is 6 fathoms in width.[13] In Crenver and Wheal Abraham, 1 to 3 fathoms in width.[14] In East Wheal Crofty (South Crofty) an elvan is 6 fathoms wide.[15] In Cardrew, 8 or 10 fathoms.[16] In Creegbrose, 4 feet to 5 fathoms.[17] In Wheal Unity, 5 fathoms.[18] In Wheal Vor there are two elvans, one 8 fathoms and the other 2 feet in width.[19] In Carn Brea an elvan is 7 fathoms wide, and another one less than this;[20] at the 300-fathom level

[1] The angle of underlie is measured from the vertical.
[2] Henwood, p. 81. [3] Thomas, p. 66.
[4] J. Maynard, "Remarks on two Cross Sections." *41st Rep. Roy. Corn. Poly. Soc.*, 1871.
[5] Henwood, p. 81.
[6] J. Carne, "On the Veins of Cornwall," *Tr. R. G.S. Corn.*, 1822, vol. ii., p. 93.
[7] Thomas, p. 16. [8] *Op. cit.*, p. 50. [9] Henwood, p. 81.
[10] *Op. cit.*, p. 83. [11] *Op. cit.*, p. 63.
[12] W. H. Argall, "On Elvan Courses." *Miners' Assoc.*, 1875.
[13] J. Carne, "On the Veins of Cornwall." *Tr. R.G.S. Corn.*, vol. ii., 1822, p. 79.
[14] *Op. cit.*, p. 82. [15] Henwood, p. 62. [16] *Op. cit.*, p. 80.
[17] Thomas, p. 34. [18] *Op. cit.*, p. 65. [19] Henwood, p. 52. [20] *Op. cit.*, p. 63.

there is an elvan 10 fathoms in width. In South Roskear there are elvans from 5 to 9 fathoms in width.[1] In Ting Tang an elvan is 24 fathoms wide.[2] In Tincroft, 6 fathoms wide.[3] In Wheal Grenville an elvan was penetrated for 40 fathoms without cutting through it.

Very few of the elvans underlie south. There are two south underlying elvans in the section of ground between South Wheal Basset and South Dolcoath Mine; and at the present time elvans which underlie south can be seen in the deep workings of Dolcoath and Wheal Grenville. Henwood (p. 80) gives two other examples. Elvans sometimes change their underlie in depth. In Dolcoath there is an elvan which in the upper part of the mine has an underlie north of about 45 deg. In depth, where the "country rock" is granite, it is almost perpendicular, underlying slightly south. At Clifford Amalgamated Mines an elvan, outcropping between Garland and Hawke's shafts, starts from surface with a northerly underlie of 70 deg. as far as the 75-fathom level, after which its underlie is 35 deg. N.

In the Gwinear district there are two series of elvans: one series strikes approximately E. 30 deg. N., aud the other series striking nearly E. and W.[4] Now, although two series cannot be identified in this district, there appears to be one elvan about 40 feet in width, which strikes nearly E. and W. between Camborne and Dolcoath.[5] At the 400-fathom in Dolcoath Mine, about 40 fathoms west of the Old Sump shaft, there is an elvan striking nearly E. and W. and underlying N. 35 deg. All the other elvans have a strike approximately E. 30 deg. N.

In the Camborne district it is particularly noticeable that the elvans in the killas, on the north of the Carn Brea Hill, are much more highly inclined to the vertical than those on the south, situated entirely in granite. The information concerning this can be generalised as follows:—The elvans cropping out on the north of North Wheal Crofty and striking westwards (W. 30 deg. S.) towards the Seton Mines vary in underlie (angle from vertical) from 47 deg. to 60 deg. N. The elvans are slightly steeper on the west than on the east. An elvan passing through South Crofty Mine underlies N. 45 deg. The elvans of West Stray Park, Carn Camborne, Dolcoath, Cook's Kitchen, Tincroft, Carn Brea, and Wheal Druid (eastern part of Carn Brea), situated along the northern margin of the Carn Brea granite, vary in underlie from 30 deg. to 45 deg. In Cook's Kitchen an elvan underlies N. 54 deg. In Wheal Druid there are two elvans; the more northerly underlies N. 37 deg. and the more southerly N. 15 deg. An elvan in South Dolcoath Mine and West Wheal Basset underlies S. 18 deg. to S. 40 deg. The elvans in Wheal Basset are in killas, and are perpendicular or inclining north. An elvan between South Wheal Basset and Carn Kie underlies S. 8 deg. The particulars of the underlies of the elvans between Scorrier Gate and the United Mines in a similar manner may be generalised as follows:—At Little North Downs Mine an elvan underlies N. 47 deg. At New Treleigh Consols an elvan underlies N. 38 deg. From Treskerby to Great Wheal Busy the elvans underlie N. from 28 deg. to 47 deg. In Killifreth the main lode accompanied by an elvan underlies N. 58 deg. In Wheal Unity an elvan underlies N. 10 deg.[6] In the Consolidated Mines the elvans vary in underlie from 30 deg. to 60 deg. N. From Ting Tang through the United Mines, Wheal Clifford and Nangiles to Wheal Jane the elvans underlie N. 35 deg. to 65 deg. (65 deg. in Wheal Jane). In Wheal Clifford the elvans becomes steeper in depth.

Throughout the whole district most of the elvans underlie north—a few only (in the granite) underlying south.

The following table gives the underlies of elvans in various mines:—

[1] Thomas, p. 42; W. H. Argall, "On Elvan Courses." *Tr. R.G.S. Corn., Miners' Assoc.*, 1875.

[2] Henwood, p. 71. [3] *Op. cit.*, p. 63.

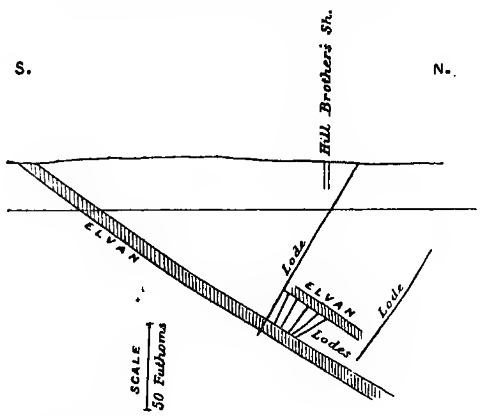
[4] Ernest Dixon (H.M. Geological Survey) *Summary of Progress*, 1901, p. 25. Mr. Dixon considers the latter series to be more recent than the former.

[5] Henwood (p. 160) quotes from a paper by Professor Sedgewick. *Camb. Phil. Trans. I.*, p. 129.

[6] Thomas, p. 65.

Mine.	*Underlie of Elvan.*	*Remarks.*
	Deg.	
Barncoose -	N. 15	Outcropping about 120 fathoms south of the Great Western Railway.
	N. 37	Two elvans outcropping about 60 fathoms south of the Great Western Railway. They are greatly branched near the surface.
	N. 46	Between Miner's shaft and Wheal Tehidy (about 180 fathoms north of the Great Western Railway).
Basset, Wheal	Nearly vertical	Two elvans, a large and a small one. They probably unite in depth.
Bell Mine -		Intersected in the mine 40 fathoms from surface. Tin occurs in it. (A. K. Barnett "On Elvan Courses," *Roy. Corn. Poly. Soc.*, 1873, p. 18.)
Buller, Wheal	N. 45 to 50	25 fathoms in width. (Henwood, p. 81.)
Baddern, Wheal	N. 59	170 fathoms south of Hillbrother's shaft. A smaller elvan 15 fathoms north underlies in the same direction. (Fig. 3.)

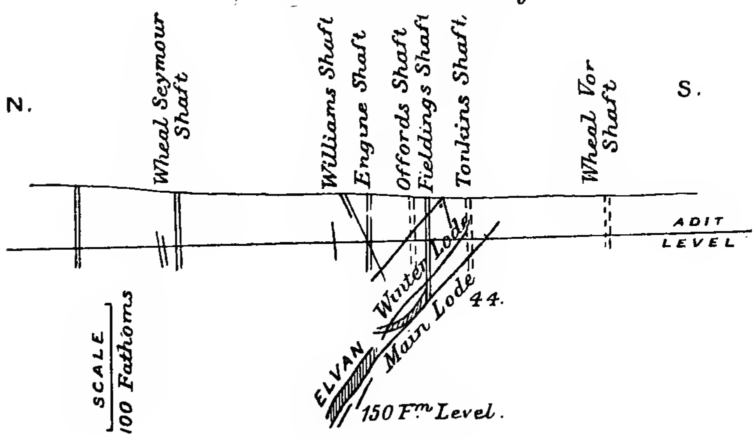
FIG. 3.—*Great Wheal Baddern.*



Mine.	*Underlie of Elvan.*	*Remarks.*
Bosleake -	S. (?)	
Busy, Great Wheal	N. 35	Fig. 4.
Consolidated Mines	N. 45 to 60	In Wheal Fortune at 160 to 200 fathoms below adit, 16 to 20 fathoms in width. (Henwood, p. 84.)
Cook's Kitchen	N. 40	20 feet wide. (W. H. Argall "On Elvan Courses," *Miners' Assoc.*, 1875.)
	N. 60	Another elvan.
Chacewater Mine	N. 47	Part of Great Wheal Busy. Elvan lies between "Winter's" and "Chacewater" lodes. 6 fathoms in width. Carne states that there are two elvans uniting in depth. ("On Elvan Courses," *Tr. R.G.S. Corn.*, vol. i., 1818, p. 104.)

Mine.	*Underlie of Elvan.*	*Remarks.*
	Deg.	
Crenver and Wheal Abraham	N. 45 to 75	1 to 3 fathoms in width. (J. Carne "On the Veins of Cornwall," *Tr. R.G S. Corn.*, 1822, vol. ii., p. 82.)
Crofty, Wheal	N. 52	
Clifford Amalgamated Mines	N. 70	Outcrops near Garland shaft. At the 75-fathom level it is directly under Deeble's shaft and underlies N. 35 deg.
	N. 57	Crops out near Moor shaft on the south of the sett.
Copper Hill -	N. 38	
Carn Brea Monument	S. 40	100 fathoms south of the Monument.
	N. 15	North of the Monument. (J. Maynard, "Remarks on Two Cross-Sections," 41*st Rep. Roy. Corn. Poly. Soc.*, 1871.)
Carn Camborne	N. 30	In depth it is vertical.
Cardrew Mine	N. 30 to 40	Near South lode. 8 or 9 fathoms in width. (Henwood, Table lxviii.)
Carn Brea Mine	Slightly North	At the 300-fathom level it is 10 fathoms in width in granite.
	N. 20 N. 40	} Seen in upper levels. (Henwood, p. 63.)

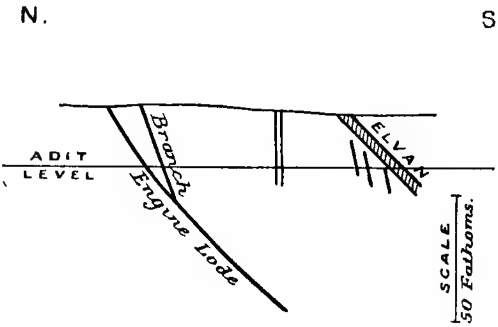
FIG. 4.—*Great Wheal Busy.*



Dolcoath -		See Remarks on Elvans in Dolcoath, in Section on Mines, p. 217.
East Pool -	N. 44	Crops out between South and Pearce's shaft.
Emily Henrietta, Wheal	N. 60	Two elvans in south part of mine about 30 fathoms apart. (Maynard's "Cross-Sections," 41*st Rep. Corn. Poly. Soc.*, 1871.)
Jane, Wheal -	N. 65	Elvan in the hanging wall of the lode.
Little North Downs	N. 47	
New Cook's Kitchen	N. 44	

Mine.	*Underlie of Elvan.*	*Remarks.*
	Deg.	
Nangiles	N. 50	
	N. 50	Near Wheal Clifford lode.
North Buller -	N. 10	
New Treleigh Consols	N. 38	Crops out between Gardner's and Carr's shafts.
New Wheal Seton	N. 47	
South Dolcoath	S. 22	
	N. 25	South of Providence lode.
South Wheal Seton (Gilly Mine)	N. 45	
Sithney Carn-meal Mine	S. 60	Crops out 100 fathoms south of the Engine lode. (Fig. 5.)

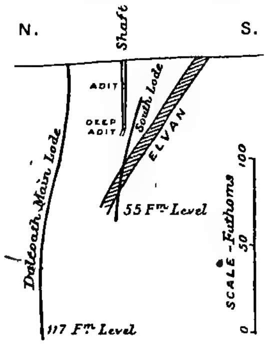
FIG. 5.—*Sithney and Carnmeal Mine.*



South Roskear	S. 10	(W. H. Argall "On Elvan Courses," *Rep. Roy. Corn. Poly. Soc.*, 1875.)
South Crofty -	N. 45	South of Bickford's shaft.
Seton, Wheal	N. 50	Crops out 60 fathoms south of Tilly's shaft.
Squire, Wheal		Elvans so nearly horizontal that they were called "Floors" by the miners. (J. Carne "On the Veins of Cornwall," *Tr. R.G.S. Corn.*, vol. ii., 1822.)
Ting Tang Mine	N. 45	24 fathoms in width. Worked for tin ore at Poldory and Ale and Cakes Mine. It sends out branches into killas. (A. K. Barnett "On Elvan Courses," *Roy. Corn. Poly. Soc.*, 1873, p. 15.)
Tincroft	N. 40	Crops out between Highburrow and Dunkin's shafts.
	N. 20 to N. 30	6 fathoms in width. (Henwood, p. 63.)
Treskerby -	N. 30	A branch from it is perpendicular up to the surface.
Tehidy, Wheal	N. 30	Crops out 30 fathoms north of Moyle's shaft.
	N. 30	
Union, Wheal	N. 61	Crops out south of Wheal Union.
	N. 45	Elvan further north than last. (Maynard's Cross-Sections, 41st *Rep. Corn. Poly. Soc.*, 1871.)

Mine.	*Underlie of Elvan.*	*Remarks.*
	Deg.	
United Mines	N. 60	Two elvans north of Chapel's shaft.
Unity, Wheal	N. 10	Irregular underlie. 25 feet wide, and continues into Creegbrose. (A. K. Barnett "On Elvan Courses," *Rep. Corn. Poly. Soc.*, 1873, p. 12.)
	S. (?)	20 feet wide. Another elvan. (*Op. cit.*, p. 14.)
Vor, Wheal	N. 50 to 57	Two elvans. The larger 8 fathoms in width. (J. Carne "On Elvan Courses," *Tr. R.G.S. Corn.*, vol. i., 1818, p. 103.)
	N. 20 to 30	Another elvan 2 feet wide. (Henwood, p. 52.)
West Wheal Basset	Vertical to S. 18	Vertical near surface.

FIG. 6.—*West Stray Park Mine.*



West Stray Park	N. 35	Fig. 6.
Wentworth, Wheal	N. 53	
West Seton	N. 58	

Subterranean Occurrence of Greenstone (Irestone, Ironstone, Iron Killas).

Pryce[1] is the first to have mentioned the occurrence of greenstone as encountered in mining operations, and states that "it often keeps a course east and west like a lode but is commonly very wide . . . . it is very tedious and chargeable where an adit must be driven through it." Charles Thomas,[2] who was a prominent mine captain in the Camborne district, asserts that greenstone never behaves like the elvan courses but occurs in "embedded masses." Some of the following facts lack confirmation, but they illustrate the subterranean extent of this rock, which is the oldest of the igneous rocks.

[1] *Mineralogia Cornubiensis*, 1778, p. 75.
[2] "Remarks on Mines in Cornwall." *Rep. Corn. Poly. Soc.*, 1854.

At Roskear, on the north of Camborne, a sill of greenstone, 20 fathoms in width, was penetrated at the deep adit level (30 fathoms from surface) at about 120 fathoms south of the South Roskear lode.[1] Another sill was encountered in the workings of the South Roskear lode from the 107 to the 139-fathom levels at least.[2] In North Roskear Mine greenstone was met with about the main lode from a depth of 30 fathoms from surface (deep adit) to 100 fathoms.[3] An old unpublished report states that the Doctor's shaft was sunk through greenstone from the 30-fathom level to the 80, after which it was in killas until greenstone was again encountered at a depth of 150 fathoms.

Greenstone was encountered in Wheal Seton between the 130 and 140-fathom levels at Tilly's shaft, which is sunk on the North Caunter lode.[4]

Greenstone with a westerly dip of 12 deg. to 16 deg. occurred at the 108-fathom level in Stray Park, Wheal Gons, and Camborne Vean.[5] In the western part Carn Camborne Mine the workings were in greenstone from the 20-fathom level (or adit) to the 50; at West Condurrow Mine (or Kellivose) greenstone was encountered when sinking was commenced on the North lode.

In South Crofty Mine a cross-cut driven north from Pryce's lode near Bickford's shaft at the 120-fathom level (near a granite ridge) encountered greenstone in the killas.[6] In the same mine a greenstone sill, about 100 feet thick, was passed through in Robinson's shaft above the 60-fathom level.[7] A little further west in the same mine the Caunter lode passes through greenstone at about the 70-fathom level, and the Copper Tankard lode was in greenstone at about the same level. Other lodes encountered greenstone in different parts of the mine from the 30 to the 75-fathom levels.[8] In East Pool Mine there are two small sills of greenstone about the Engine shaft at the 48-fathom level. They have a northerly underlie. At North Pool there is a sill of considerable thickness, outcropping about 60 fathoms south of the main shaft and underlying north at about 54 deg. from the vertical.[9] A greenstone sill 20 fathoms in width was found in the upper part of Tincroft Mine.[10] Further east there appears to be a sill of greenstone at about the 20-fathom level in Barncoose Mine. At Wheal Union, near Redruth, greenstone is said to have been encountered at about the 80-fathom level. In Trevaskus Mine, Gwinear, greenstone occurs in the walls of the lodes at the 33, 51, 66 and 71-fathom levels.[11]

In the killas, on the north of the Carn Brea granite, there appears to be two prominent but irregular sills of greenstone. The sill seen in North Pool Mine may be the same as that seen in North Roskear and Wheal Seton. The other appears to extend from Barncoose through East Pool, South Crofty, to South Roskear, and the sill observed in Tincroft Mine probably represents that intrusion.

[1] Thomas, p. 18. [2] Henwood, Table liv.
[3] M. L. Moissenet, "Filons de Cornouailles," 1874.
[4] H. C. Salmon, *Mining and Smelting Magazine*, 1862, vol. ii., p. 282.
[5] Henwood, Table xlix.
[6] J. Maynard, "Remarks on Two Cross Sections." *Rep. Corn. Poly. Soc.*, 1871. Thomas, p. 18.
[7] Information from John Penhall, manager of South Crofty, Carn Brea, and Tincroft Mines.
[8] Henwood, Table lvi. [9] See "Cross Sections," by J. Maynard (*op. cit.*)
[10] J. Carne, "On the Veins of Cornwall." *Tr. R.G.S. Corn.*, vol. ii., 1822, p. 61.
[11] Henwood, Table xxxv.

CHAPTER XIV.

NATURAL HISTORY OF THE LODES.

I. Distribution of the Lodes.

The lodes of the area are almost entirely confined to the western district, and are mainly restricted to the neighbourhood of the

Figs. 7 to 16.—*Series of Cross Sections through the Mining District of Camborne and Redruth.*

Fig. 7.—*Section from South Tolcarne Mine to New Wheal Seton.*

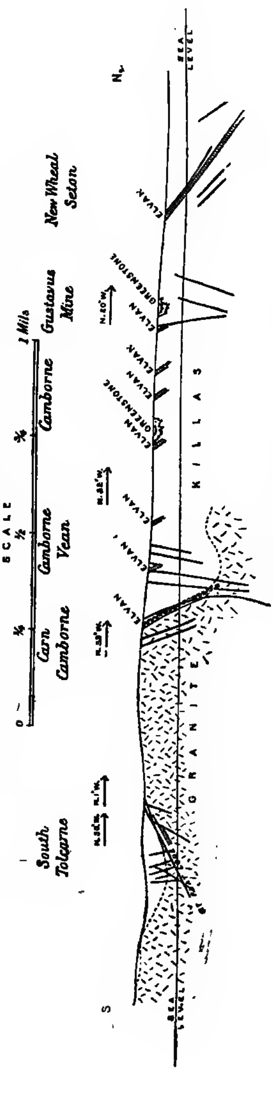
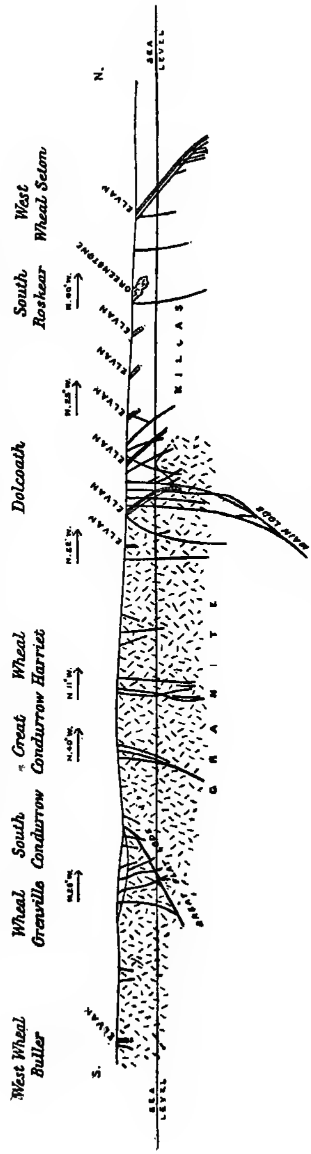


Fig. 8.—*Section from West Wheal Buller to West Wheal Seton.**



* For scale see Fig. 7.

granite, and more especially near its margin; but they continue to occur for a distance of 4 miles eastward of the granite. Thus the country lying between Baldhu (on the east) and Camborne (on the west) and extending for a few miles north to a few miles south of Redruth includes the principal mining area of this map. (See Fig. 1.)

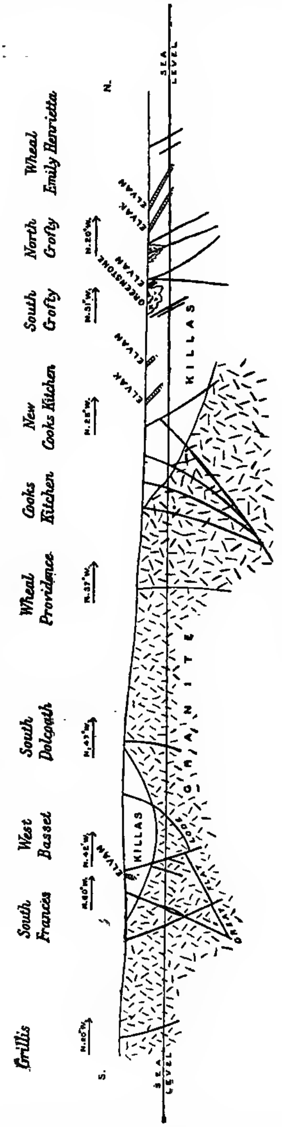


FIG. 9.—Section from Grillis to Wheal Emily Henrietta.*

* For scale see Fig. 10.

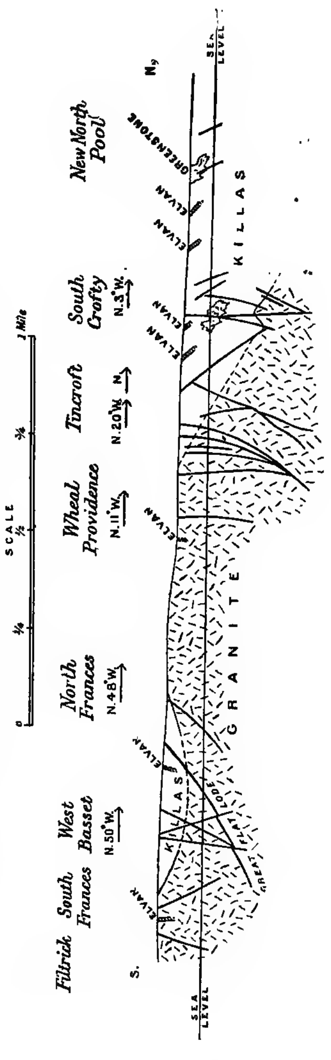


FIG. 10.—Section from Filtrick to New North Pool.

For simplicity this district can be roughly divided up into mineralised areas without separating the lodes genetically. Thus, the margin of the Carn Brea granite is the site of a remarkable series of tin and copper lodes (striking N.E.×E., approximately parallel to the granite margin), extending from Camborne to Redruth. The

lodes of this mineral belt which are situated but little more than three-quarters of a mile north of the granite margin, are of no great value. Near the margin, however, the lodes have been enormously productive in tin and copper ores for a distance of at

FIG. 11.—*Section from Wheal Basset to North Pool.**

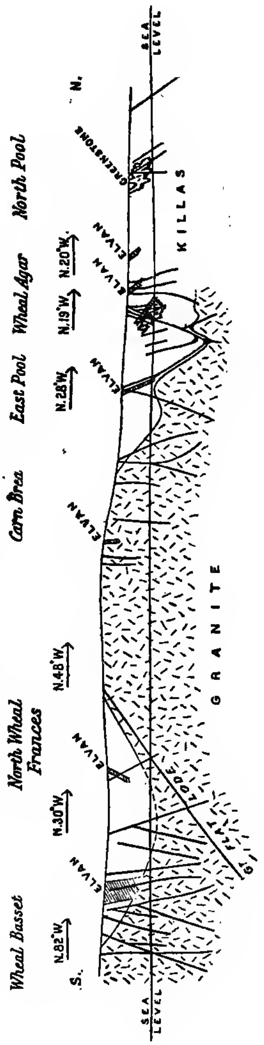
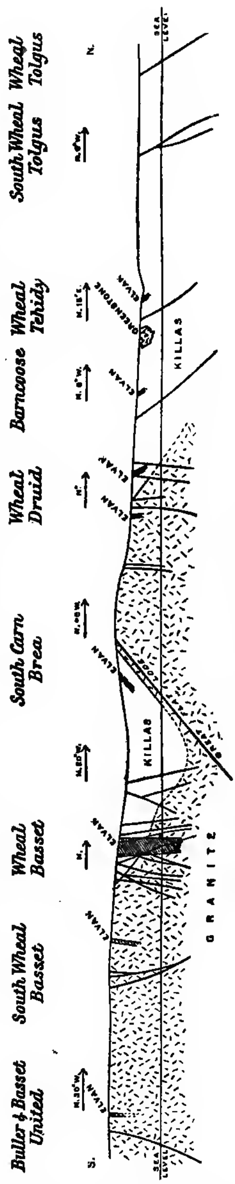


FIG. 12.—*Section from Buller and Basset United to Wheal Tolgus.**



* For scale see Fig. 10.

least 3 miles along their strike. The lodes on the north of the Redruth (or Carn Marth) granite may be considered as being in the eastern extension of the same belt.

Between the Carn Brea and Carnmenellis granites there occurs

FIG. 13.—*Section from West of Penstruthal to Tolgus United.**

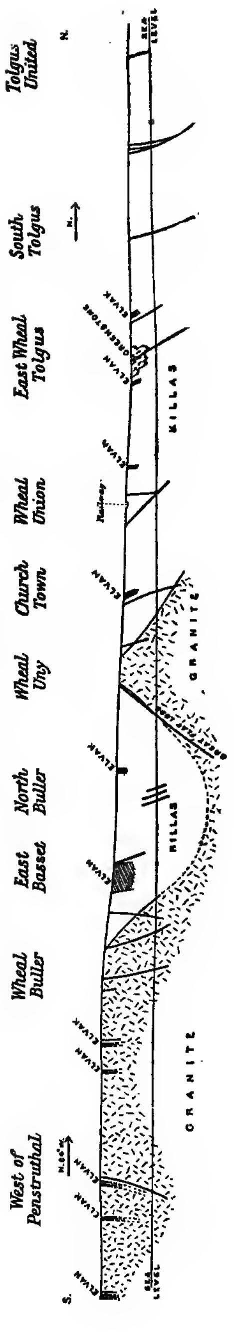
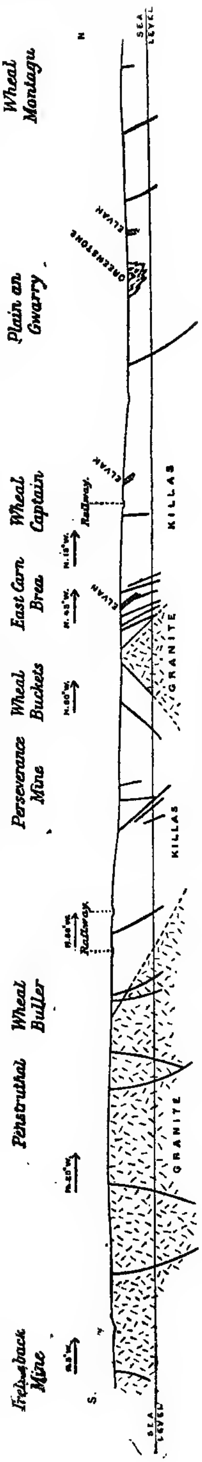


FIG. 14.—*Section from Trelusback Mine to Wheal Montagu.**



* For scale see Fig. 10.

Fig. 15.—*Section from Tresavean Mine to Treleigh Consols Mine.**

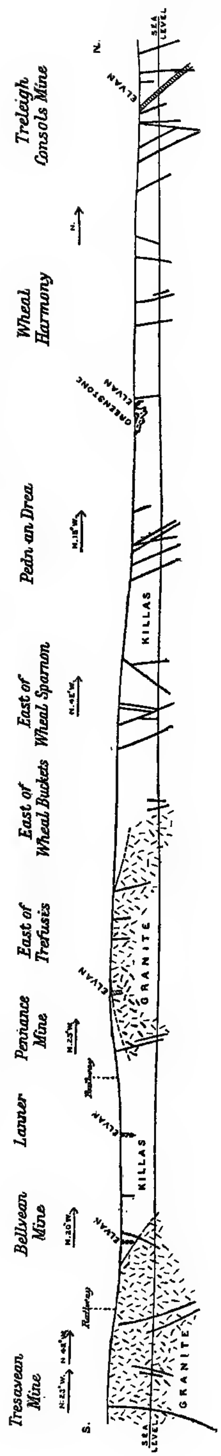
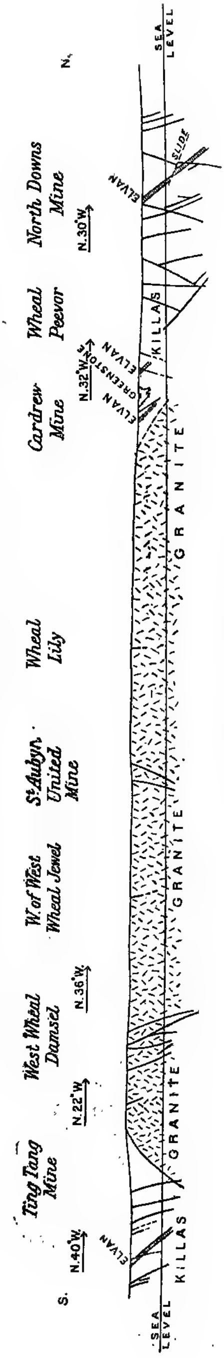


Fig. 16.—*Section from Ting Tang Mine to North Downs Mine.**



* For scale see Fig. 10.

a prominent series of lodes, of which the Great Flat lode is the largest member. The series extends from the west of South Condurrow Mine to Carn Marth (on the east)—a distance of 3½ miles. (See cross sections, Figs. 7 to 16.) On the west of the Carnmenellis granite is the mining district of Gwinear and Crowan. Here and there, around the same granite mass and in the more elevated portions of the interior, from Wendron to Halabezack, are lodes containing both tin and copper ores. Finally, there is the Porth Towan group of lodes near the sea coast on the north of this map.

II. Geological Age of the Lodes.

In discussing the ages of the lodes, it should not be assumed that the mineralisation of a fissure commenced immediately after its formation. Carne's classification* of the lodes into six systems appears to imply that movements operated successively for the production of fissure systems, and that each movement was accompanied not only by a series of fissures, but by a distinct period of mineralisation. The fissures of a single zone of fissuring, or of a whole fissure system such as either of those referred to on p. 205, may be assumed to have had a common mode of origin. The process which produced the fissures should be regarded as a progressive or long-continued one, so that the fissures first formed should not be separated from the last. In speaking of the age of the lodes, therefore, a period is implied during which two operations may have gone on hand in hand—(1) fissuring, (2) mineralisation. Reference will be made elsewhere to the order in which the minerals arrived, but it may be mentioned incidentally that it appears to be this which accounts to a certain extent for the confusion that has arisen regarding the relative ages of the lodes. The tin and copper lodes may be broadly described as of post-Carboniferous but pre-Triassic age.† In Cornwall and Devon this epoch is characterised by an intrusion of granite, which in fact appears to have been the culminating effect of great earth movements. The direction assumed by the lode fissures formed after the consolidation of the granite appears to have depended upon the structures produced by these pre-granitic movements. Indeed, lines of weakness so formed do not appear to have become fissures capable of the reception of minerals until after the intrusion of the elvans. The process by which the fissures were mineralised was probably long-continued.

III. Relative Age of the Tin-Copper and Silver-Lead Lodes.

Besides tin and copper, other minerals occur in the lodes, and of these the ores of silver and lead are among the more impor-

* *Tr. R.G.S. Corn.*, 1822, vol. ii., p. 49. † See De la Beche, p. 283.

tant. Geographically, the distribution of the ores of lead and silver in the district is comparatively wide, but their economic importance under present conditions is small. They occur in districts outside the great tin and copper centres, but they are also found in lodes containing tin and copper.

The arrival of the silver-lead ores appears to have been delayed to a late period in the history of the metalliferous veins of the district, since although they occur in a number of east and west lodes, they continued to arrive after the lodes of tin and copper had been completely formed; and, indeed, these ores were still being deposited during the later phase of movement, which resulted in the production of cross courses (or cross faults). Many of these cross courses contain ores of silver and lead and other minerals of less economic importance. Tin and copper ores had entirely ceased to arrive during the formation of the cross courses.

IV. Structure of the Lodes.

Many lodes have been formed intermittently by operations extending over a lengthened period, with the result that they frequently display a variety of structures. The veinstones of the lodes show that they have originated in one or more of three modes of production :—

1. Infilling of a fissure or series of close parallel fissures by minerals derived from a distant source.

2. Alteration and impregnation of the country rock in the vicinity of a fissure or fissures by minerals derived from the fissure.

3. Alteration and impregnation of a friction breccia contained in a fissure (modification of 1 and 2). (Plates X. and XI.)

The simplest structure which a lode can have is the comby or platy structure. Here the lode is built up of layers parallel to the walls, each layer representing a period of deposition and also, possibly, a widening of the fissure. In the "tin-copper" lodes the comby structure is not rare, but is mainly seen as the linings of actual cavities, particularly in the upper parts of lodes. In some fissures completely filled with quartz the "combs" are clearly seen interlocking in the middle of the vein.

The Cathedral Mine, near Redruth, shows successive depositions of quartz, fluorspar, and copper pyrites in the lode; and at Wheal Julia, near Binner Downs, the layers consist of quartz, blende, and copper pyrites.* At Wheal Tolgus a specimen shows the order: quartz, blende, and iron pyrites. A table prepared by Henwood† shows that a definite order of mineralisation can be made out in the lodes of many mines. The mineral which occurs most frequently against the walls of lodes is quartz; and in tin lodes tin is also in this position. When wolfram occurs it is likewise here. The next appears to be principally sulphides of copper, with occasionally galena, and sometimes iron and man-

* De la Beche, p. 340. † p. 214.

ganese minerals and arsenical ores with blende, associated with quartz, fluorspar, chlorite, and other veinstones.

Another form of banded structure is that produced by the infilled fissure and the country rock, which for a short distance on each side has been altered into "capel." This alteration in the walls is characteristic of the tin lodes, and in some cases the country rock in the vicinity of the fissure is worth breaking down for the tin ore it contains. Thus the stanniferous deposits of East Wheal Lovell consist of altered granite, in the neighbourhood of fissures, impregnated with tin ore.* In some cases the lode has a banded appearance, the origin of which is interesting. The lode may consist of a series of narrow parallel cracks or joints, through which at one time mineralising solutions were passing, with the result that the lode consists of a series of narrow strings, containing cassiterite or wolfram, quartz, &c., enclosed by bands of altered country rock.† In other instances the original character of the fissures is obscure, as sometimes the cracks or joints are so close together that the intervening layers of country rock are completely altered, while at the same time the fissures have been obliterated. Sometimes, where the lode appears to be massive, minute lines of rifting can nevertheless be seen, through which, no doubt, the changes in the walls of the lode were effected.‡ A microscopic degree of fineness, in which the lines are so closely packed that the rock appears homogeneous, is sometimes discernible.

Modifications of these structures are very interesting, as accounting for the presence of strings of chloritic material, or for veins and plates of "peach" (fine-grained schorl rock) which not infrequently occur in the lodes in both granite and killas. Some of these cases may be explained as follows:—The first fissure infilling firmly cemented itself to the walls of the fissure, but when the fissure re-opened at a later time it did so along a plane of weakness parallel to the lode, but in the band of altered country rock alongside the original fissure infilling. In this manner a plate of altered country rock became detached and enclosed in the lode between old and new infillings. In some cases, especially in killas, where the lode is parallel to the cleavage, this has happened again and again, so that each fresh re-opening of the fissure took place on the outside of a thin sheet of country rock, which remained firmly attached to the lode. A similar explanation may be applicable in many cases to the presence of more irregular masses in the lodes (*e.g.*, horses), and to go a step further is to arrive at a structure which resembles a breccia. Breccias in lodes are not rare, but they also originated in a variety of other ways.

* C. Le Neve Foster, "Remarks on the Tin Deposits of East Wheal Lovell." *Tr. R.G.S. Corn.*, 1876, vol. ix.

† Illustrations of similar structures are to be found in "Mineralogischen Geographie," by J. F. W. Charpentier, 1778.

‡ An excellent account of the connections of ore deposits with joints will be found in "Ore Deposits of Monte Christo, Washington," J. E. Spurr. *U.S. Geol. Survey 22nd Ann. Rep.*, 1900–1901. Instructive examples of the structure of lodes will be found in the various publications of the U.S. Geol. Survey by such authors as Ransome, Adams, and Spencer.

Locally, the breccias were again brecciated by movements taking place in the plane of the lode.* In other places the lode cracked, and the walls slid over each other, so that the vein materials were sheared out and crushed. Phillips says that "in many instances the original opening would appear to have been a mere comminuted fracture of the rock in a given general direction, between the several planes of which a deposit of mineral substance has subsequently taken place through chemical agency. The final result in such a case will be a brecciated veinstone of the kind so constantly met with in mineral districts."†

The structure of lodes in the killas is, on the whole, more varied than of those in granite. Some lodes are of enormous width, and consist of zones of crushed and dragged-out fragments of killas, filled with granite and metalliferous minerals. In the Dowgas Mine (St. Austell), for instance, the "Goffin" lode in some places attains 50 feet in width, and it is difficult to say exactly where the lode ends and the country rock begins. In the neighbourhood of Ventonwyn Mine (St. Austell), the cleavage of slates is nearly horizontal, or dip gently northwards, but in the vicinity of the main lode of that mine the dip of the slates is greatly increased until it becomes parallel to the lode which underlies steeply northwards. In this case the slates were bent, dragged out, and broken by the sliding downwards of the hanging (or north) wall of the lode. Slickensides are common. In other cases the killas in the vicinity of the lode is contorted and gnarled, and traversed by irregular lenticular quartz veins, and in appearance very like some of the structure depicted in the *Kingsbridge and Salcombe Memoir*.‡ Instances of gnarling in the vicinity of the lode have been noticed in the St. Agnes district.§

Another kind of lode structure is that which depends upon the infilling of the interstitial spaces, and the alteration and impregnation of the crushed material of friction breccias. In the Camborne district this type of veinstone is extremely common, and many modifications of it are represented. Thus the lode may consist of an interlacing network of stanniferous and quartz veins, enclosing fragments of altered country rock. This breccia may be brecciated again and again, and each time sealed up by infiltrated minerals. Thus at Wheal Basset a specimen of veinstone shows at least four successive operations of crushing and healing up. The lodes of Dolcoath, South Crofty, and East Pool also typify this sort of structure. Lodes in killas generally contain a great amount of that material, either as large broken masses or small fragments. In granite the lodes very frequently

* J. H. Collins, "Cornish Tin Stones and Tin Capels." *Min. Mag.*, 1882, p. 15. J. S. Flett (H.M. Geological Survey), "Notes on Some Brecciated Stanniferous Veinstones from Cornwall." *Summary of Progress*, 1902, p. 154. "Petrography of West Cornwall." *Summary of Progress*, 1903, p. 158.

† J. A. Phillips, "Lodes of the Mining Districts of Cornwall." *Q.J.G.S.*, vol. xxxi., 1875, p. 341.

‡ By W. A. E. Ussher, 1904, see pp. 7 and 8, and Fig. 3.

§ C. Le Neve Foster. *Tr. R.G.S. Cornwall*, 1877. "Remarks on Some Tin Lodes."

have what is known as a "granitic structure." In this way the lodes vary in composition according to the nature of the country they traverse.

The formation of crush conglomerates is locally characteristic of some of the lodes. In South Wheal Frances, at the 82-fathom level, or 105 fathoms from surface, near the middle of the copper lode, rounded stones (granite) were found, all of them apparently moved away from the places originally occupied by them by disturbances in the lode. Some of them were embedded in copper ore.

Pieces of granite the size of the palm of a man's hand were found embedded in the lode in the eastern part of Carn Brea Mine,† where the lode was disturbed by a cross course.

The occurrence of conglomerate in the lodes of the adjacent mineral district of Gwinear was more common. At East Relistian pebbles cemented by copper ore and iron pyrites occurred.

The infinite variety of structures presented by some of the great lodes of the Camborne district almost defies description. The enormous excavations alone remain in many cases as mute witnesses of the size and value attained by the deposits of this district. In some cases, as for instance in East Pool Mine, the country rock for a great distance on either side is highly altered by silicification, &c., and, indeed, it is a matter of difficulty to see a really fresh piece of granite, except at considerable distance from the lodes. Alteration of the country rock in the vicinity of the lodes is exhibited on a large scale in other mines, as for instance Dolcoath, Wheal Grenville, &c.

Observation in Dolcoath Mine shows that this extensive alteration of the country rock does not take place from a single fissure. It sometimes happens that the lode consists of two or three or more cracks or fissures, along which the solutions have flowed at the time the lode was being formed; they may be more or less parallel, but very often it appears that the country rock is so shattered near the lode that the mass would be better described as a breccia. The country on either side of these cracks has been completely changed, so that no fresh, unaltered rock remains in the space between the cracks. Thus at the 412-fathom level in Dolcoath Mine, between the Eastern and New Sump shafts, the lode contains two or three parallel fissures which are only discerned with difficulty, since they are very narrow and cemented up. The lode here, for several feet in width, is a dark, hard, schorl rock containing tin in certain parts. The country granite near the lode has been taken away for the tin it contains, which is generally in the form of strings. At the 375-fathom level very numerous small, irregular strings penetrate from the main lode into the country rock, and the tin contained in them and their neighbourhood has warranted the excavation of a considerable piece of ground. These generally are regarded by the miners

* John Rule, "Notice of the Discovery of Several Rounded Stones in the Lode at South Wheal Frances." *Tr. R. G. S. Corn.*, 1847-65, vol. vii., p. 161.

† W. H. Argall, "On the Elvans of Cornwall," *Miners' Assoc.*, 1875.

as droppers or feeders, since they are supposed to feed or enrich the lode. At the 375-fathom level the main lode is clearly seen in a stope on the west of the Eastern shaft. At this point the lode consists of a small band of soft, light blue peach, on the north or foot wall of which the granite is altered for several feet into tough schorl rock (" peach "). On the south or hanging wall the granite is altered, but not to schorl rock. On the south there is a dropper (or off-set) underlying north, consisting of schorl rock. The wedge of ground between the dropper and the main lode at this place has been worked away for tin ore. On a much larger scale the granite between the South lode and the north part of the main lode has been excavated to a great extent. The South lode and the north part of the main lode between the New Sump shaft and the Eastern shaft converge in depth and unite at the 400-fathom level. Both these lodes and the country rock between them from above the 375-fathom level downwards have been worked to an enormous extent, and the size of the immense caverns formed by the stoping away of this rich tin ground for many fathoms in breadth and height is but faintly appreciated by the dim light of the miners' candles. The country rock between the lodes above mentioned is traversed through and through by small strings, so that the mass is really a breccia on a large scale containing tin ore.

It may happen that the initial fissure in which the lode was produced has left some trace of its original form in the occurrence of a persistent tin, quartz, or schorl rock vein. In such cases these features may act as indicators, or leaders, to guide the miner in driving and opening up the lodes. Leaders are, however, generally of more recent origin. A smooth wall, a clay flucan, or parting filled with clay, quartz, fluorspar, chalybite, &c., may also act as leaders. The leader at Wheal Uny is in one part 18 inches wide, consisting of a mass of fragments of more or less altered killas (capel), with some tin oxide, and it soon dwindles down to a mere flucan, or vein of clay, with a little quartz, only 2 inches wide. The sides (walls) are very smooth, presenting numerous slickensides; in fact, the leader has all the appearance of being a mere crack, filled, in the main, mechanically, by fragments of the sides reduced in places to a clay by the attrition of the walls."* At South Carn Brea Mine this leader becomes a copper lode 2 to 4 feet wide, and in West Wheal Basset the leader of the same lode was frequently reduced to a mere ferruginous joint. At West Wheal Frances (on the west) the leader becomes a quartz vein 2 or more feet wide, but it is generally poor in tin.†

In Wheal Grenville the leader sometimes consists of a very hard, fine-grained schorl rock, of the usual lode type, varying in thickness about a foot or so, but occasionally dwindling down until it disappears altogether, or changes its character to a ferruginous clay or quartz vein.

* Foster, p. 641. † *Op. cit.*

At Great North Wheal Seton a flucan, or clay parting with some vein quartz, occurred in the lode. The North Tincroft lode in Cook's Kitchen Mine is 3 to 6 feet in width and consists of quartz and soft killas. The leader is a vein of crushed fluorspar ("can") 3 inches in width.

In East Wheal Lovell the lodes are very narrow, "sometimes a mere joint or line of division in the rock, but occasionally a couple of inches thick; they consist of quartz, a little clay, and red oxide of iron, and *per se* are utterly valueless." These are regarded as the leaders, the valuable ore occurring as impregnations of the country rock.*

A few common types of veinstone or altered country rock near the lodes have received special names, as Capel, Peach, Prian, and Scovan.

Capel.—The following is from Pryce's old book†:—"The Scovan lode, when in decay for tin, will commonly degenerate into a caple, which, in fact, is mostly of the nature of a scovan lode's walls, or that enclosing stratum, which it is in contact with; thence called the caples or walls of the lode. But there is really such a thing as an original caple lode, properly so called; which abounds with a very stiff, hard stone, something like a limestone, except the colour, wherein the tin is sometimes veined, and other times very small and disseminated. A primary caple lode is promising for tin, though but seldom for copper, unless there is a branch of copper ore or gossan that veins downwards in the lode."

In the glossary of terms in the same book, Pryce says:—

Capel is "a sort of stone something like limestone, but will not burn. The walls of most lodes are of this kind of stone, therefore it is common to call the walls of a lode by the name of its caple. Also some veins which abound in this stone are termed caples, or caple lodes." William Phillips‡ says that "a vein is termed a caple lode when consisting of a hard, compact and unpromising substance which seems principally to be quartz intermixed with minute portions of chlorite, giving a greenish or brownish-green tinge to the mass. Tin is often found in it, copper rarely. But if a branch of copper ore, or a gossan be found to take its course down the vein, it commonly makes a durable copper mine."

"Of this word it is almost impossible to give a definition, as it refers rather to situation than to substance."§ "The word capel refers rather to situation than substance, but it generally appears to be a hard homogeneous stone, of a grey or bluish grey, with no structural peculiarities."‖

Phillips states that the hard quartzose altered country material in the vicinity of the lode, if not carrying tin, is called "capel." Under the microscope it is quartz and chlorite, or quartz and tourmaline with unaltered country rock.¶ "Capels are most frequently composed of a quartzose base through which crystals of schorl are very thickly disseminated either in the form of spheroidal aggregations radiating from various centres, or as acicular crystals crossing one another in all directions. Sometimes, particularly when they occur in slates, capels are a mixture of quartz and chlorite; in others, both chlorite and tourmaline are present. They also often contain innumerable fragments of the country rock, and are traversed by narrow strings of quartz into which project hair-like crystals of schorl, which are generally attached to the sides of the enclosing fissure. In addition to the foregoing,

* Le Neve Foster, "The Tin Deposits of East Wheal Lovell." *Tr. R. G.S. Corn.*, 1876, vol. ix., p. 4.

† *Min. Cornub.*, 1778, p. 90.

‡ *Tr. Geol. Soc.*, vol. ii., 1814, p. 119. "On the Veins of Cornwall."

§ J. Carne, "On Elvan Courses." *Tr. R.G.S. Corn.*, vol. i., 1818.

‖ Thomas, p. 19.

¶ J. A. Phillips and Henry Louis. "A Treatise on Ore Deposits," 1896.

capels frequently enclose crystals and crystalline groups of quartz (traversed by belonites of schorl), which sometimes appear to have been broken by contraction or otherwise, and afterwards repaired by a growth of schorlaceous matter within the crack."* Foster, speaking of Penhall's Mine (St. Agnes), says that "the word capel is applied to a rock which appears to me to be simply a highly altered killas—a killas which has been greatly acted on by mineral solutions, and changed from a soft, slaty rock into a hard, dark-coloured compact mass of quartz and schorl, these minerals being arranged in streaks following the original lines of stratification of the killas. In addition, the capel is generally full of short lenticular veins of quartz, and is intersected by numerous little strings of cassiterite and chlorite."*

In Wheal Uny, situated on the Great Flat lode, the lode lies between granite and killas in one place. Here the leader "is 18 inches wide, consisting of a mass of fragments of more or less altered killas (capel), with some tin oxide," while the term "greyback" is reserved for the altered granite which is found below the lode, consisting of "schorl rock with large grains of quartz in a compact black matrix."‡ In the part of Wheal Uny, where the lode is entirely in granite, the word capel has a different meaning. The capel here is found in the granite below the lode and is a "compact" schorl rock, with spots and veins of quartz, containing a very little tin, 2 feet thick." The "greyback" lies just beyond, and consists of a "schorl rock with large grains of quartz in a compact black matrix." This shades off into "country" granite.§ In South Carn Brea Mine there is formed in the granite, below the copper lode, a "more or less stanniferous schorl rock, *i.e.*, lode or capel," while above the copper lode, in killas, the capel consists of "schorl rock derived from killas." In West Wheal Basset the tin lode is entirely in granite. Here the stanniferous lode shades off into slightly or non-stanniferous schorl rock. In South Condurrow the same lode is entirely in granite and has a capel consisting of compact schorl rock above and below the lode; that "above the lode is much veined with quartz and contains little or no tin." At Wheal Grenville the capel for about 2 feet on each side contains 1·6 per cent. of tin ore (36 lbs. of black tin per ton), whilst the capels left standing contain ½ to 1 per cent. of tin ore.‖

Mr. Collins states that "capels are the silicified walls of fissures, they occur more especially in tin mines, and often, indeed, contain enough tin to pay for working, but they are known also in lodes yielding copper, lead, zinc and iron."¶ "The substance known in Cornwall and Devon as capels may be described as highly altered and usually silicified bands of country rock, bordering a more or less distinct fissure or fissure-filling. The term is sometimes applied to a silicified or mineralised band at the side of a fissure traversing granite or even elvan, but most well-marked capels occur in killas. Tin capels contain particles of tin oxide in notable proportions, though not always in quantities sufficient to pay for working."**

PEACH.—Pryce†† states that "a peach, or peachy lode, takes its name from a kind of stone, which principally abounds in the lode, and is generally of a spongy texture, and of a greenish or dark green olive colour. It is better for tin than copper; but is not a desirable lode for either, especially the latter, which is always of a poor quality and value when found in a peachy lode."

* J. Arthur Phillips, "Rocks of the Mining Districts of Cornwall." *Q.J.G.S.*, 1874, vol. xxxi., p. 341.

† "Remarks on Some Tin Lodes in the St. Agnes District." *Tr. R.G.S. Corn.*, 1877, vol. ix.

‡ Foster, p. 642. § *Op. cit.* ‖ *Op. cit.*

¶ J. H. Collins, "Origin and Development of Ore Deposits." *Journ. Roy. Inst. Corn.*, 1892, p. 86,

** *Op. cit.*, p. 157. †† *Min. Cornub.*, 1778, p. 90.

William Phillips* says that "a vein that contains a great proportion of chlorite is termed a peachy lode."

Carne writes that peach is chlorite; or mica if it is tinged with green.†

Professor Foster remarks that the "green peach of the Cornish tin mines is undoubtedly chlorite, but the so-called 'blue peach,' which is so large a constituent of the tin lodes of such mines as Dolcoath, Cook's Kitchen, Carn Brea, West Basset, &c., is a bluish grey variety of tourmaline."‡ Specimens of peach from Dolcoath and Wheal Basset, examined by Dr. Flett, show it to be fine grained and dark green or bluish green in colour and "while in some cases it is so fine as to be crypto-crystalline in appearance, in others it is visibly composed of little acicular needles." Light-coloured peach from Dolcoath shows under the microscope many aggregates of pale mica, which appear to be altered remains of felspar, no doubt derived from the country rock," and "owing to the abundance of finely-divided chlorite" was green in colour, "while tourmaline was present only in small quantity." The blue or dark blue varieties from Dolcoath and Wheal Basset are rich in tourmaline."§

PRIAN.—"A vein is said to be a pryany lode when the tin or copper ore does not occur in a compact state, but when the stones containing either of them are found mixed with other substances such as gossan or fluccan."‖ A term applied to a vein material of tin and copper lodes which consists of loose, crumbling ferruginous mixture of clay and quartz grains, and sometimes mica. The clay by itself would be called fluccan, while a ferruginous loose quartzose vein infilling is known as a "gossany" or "sparry" veinstone.

SCOVAN.—Pryce¶ says that a "scovan lode is formed of a hard compact crystalline stone either of a brown or black hue, according to the colour of the tin with which it is mixed. The ore is often rich, ponderous and solid in this stone, and when it is worth one half for metal they call it scove."

William Phillips states that "when tin ore is intimately mingled with quartz and chlorite the vein is termed a scovan lode, which is of a dark brown or of a greenish hue, but not very hard or compact. It sometimes occurs in a vein the contents of which are not solid, thence by the miners termed a sucked stone."** This substance is a "hard blackish stony matter."†† Hunt describes it as tin ore mingled with quartz and chlorite of a dark brown or dirty green hue, generally loose textured.‡‡

CAVITIES OR "VUGS" IN LODES, &C.—In the Dolcoath main lode, at a depth of 175 fathoms from surface, a large cavity was discovered about the year 1814. It measured 18 to 20 fathoms in length, 3 fathoms in height, and from 4 to 9 feet in width. Carbon dioxide was present in quantity sufficient to extinguish a candle flame.§§ At the 352-fathom level in the main lode the granite is soft and the lode "vuggy."‖‖ At the 462-fathom level in the same lode there are several vugs. One of them is an irregular cavity of about 12 feet in length, 6 feet in height, and 4 feet in width. The ground in which it is enclosed is very rotten.

* "On the Veins of Cornwall." *Tr. Geol. Soc.*, vol. ii., 1814, p. 118.

† "On Elvan Courses." *Tr. R. G.S. Corn.*, vol. i., 1888.

‡ "New Mineral Localities." *Min. Mag.*, 1877, No. 3.

§ J. S. Flett, "Stanniferous Veinstones of Cornwall." *Summary of Progress of Geol. Survey*, 1902, p. 155.

‖ W. Phillips, "On the Veins of Cornwall." *Tr. Geol. Soc.*, vol. ii., 1814, p. 119.

¶ *Min. Cornub.*, 1778, p. 90.

** "On the Veins of Cornwall," *Tr. Geol. Soc.*, vol. ii., 1814, p. 118.

†† Thomas, p. 34. ‡‡ Robert Hunt, *British Mining*, 1884.

§§ John Rule, "Cavern in Dolcoath Mine." *Tr. R. G. S. Corn.*, 1818, vol. i., p. 225.

‖‖ R. J. Frecheville, "Notes on the Great Main Lode of Dolcoath." *Tr. R. G. S. Corn.*, 1883, vol. x., p. 147.

A vug containing phosphate and arsenate of lead with quartz occurred in the lode at Wheal Rose, in the parish of Sithney.*

At the Consols Mine (Gwennap) a "great cavity or vug was found, many fathoms in length and height," at the bottom of which a mass of brecciated copper ore was met with, some of which had evidently fallen from the upper part of the cavity.†

At Great Condurrow Mine a vug was encountered in the main lode at the 155-fathom level; the length is 36 feet, height 12 feet, width 2 or 3 feet.

Horses.—Large pieces of the country rock, which are entirely surrounded by lode matter (that is, round which the lode has formed), are called "horses." In Dolcoath Mine there are at least three "horses" of granite in the main lode. The largest is at the 425-fathom level, and measures 40 fathoms in length and 15 fathoms in thickness. In depth it has not yet been proved. Other "horses" occur at the 210-fathom level, between the Old and New Sump shafts, and at the 352-fathom level on the east of the New East shaft.

"Horses" were encountered in Binner Downs Mine, Cook's Kitchen, and other mines.‡

Walls of Lodes.—The transition between the payable lode and altered country rock is often gradual, and it is probable that the grinding of the walls upon one another, together with the corroding or altering action of solutions traversing the fissures, have obliterated the original walls in many cases. Thus the Great Flat lode has no sharp bounding walls, and, except for many faces or joints in the lode running in the same direction, the lode gradually dies out laterally in the country rock. Many parts of the Dolcoath main lode show similar characteristics. In Cook's Kitchen Mine, at the 145-fathom level on the Highburrow lode, the lode is 10 feet wide. The granite walls are more or less ragged or rough in appearance, and on close inspection the wall rock is seen to cleave most readily along irregular planes rudely parallel to the walls. These are sometimes narrow cracks filled with lode material. The country is occasionally so shattered as to be really a mass of impregnated rock, enclosing a number of irregular open or closed fissures, situated near to one another. In the country rock of the Highburrow lode in Tincroft Mine there is occasionally a fairly well-defined cleavage or jointing, which strikes more or less in the direction of the lode, but is inclined more towards the vertical than the south underlying Highburrow lode. These joints do not appear to traverse the lode, and are mineralised to a very slight extent with a little tourmaline or quartz, or they are simple clean cracks. On the other hand, many of the lodes are bounded by sharply-defined walls. The North Entral lode at Dolcoath shows clean bounding walls in many places, but the walls are nevertheless considerably altered.

* Hugh Stephens, "Mineral Phenomena of Wheal Rose." *Rep Corn. Poly. Soc.*, 1871, p. 77.

† De la Beche, p. 324. ‡ Henwood, p. 176.

V. Caunter Lodes.

"Cornish miners always give the name of a contra-lode, or caunter, to those veins which do not hold the directions of their main lodes, and therefore what may be termed a contra-lode in one district coincides in direction with the normal lodes of another; thus the lodes of the southern part of the St. Austell district coincide with many contra-lodes in Gwennap, Camborne, &c., and the direction of some of the contra-lodes in the former coincides with the true lodes of Gwennap, &c."* Pryce† states that Caunter lodes frequently cut through all lodes except the cross gossans (cross courses), but points out that lodes which intersect are caunters with respect to one another. Richard Thomas‡ states that the general course of the lodes in the Camborne and Redruth districts is from E. 20 deg. to E. 40 deg. N., and that the Caunter lodes vary in direction from this course from 30 deg. to 40 deg. Joseph Carne§ says that the contra-lodes are metalliferous veins, whose direction is from E. 30 deg. S. to E. 40 deg. S., but that some run in an opposite direction.

The following relates to the Dolcoath Caunter lodes:—

The North or Valley Caunter Lode branches off from the main lode near the Gossan shaft and strikes E. 60 deg. N. for some distance until it encounters the South Entral lode. It is really a branch of the main lode. With a southerly underlie of 5 deg. it yielded immense quantities of copper ore to the 130-fathom level.

The Dolcoath Caunter Lode.—Henwood|| states that the Caunter lode faults Harriett's lode (which has bearing E. 30 deg. N.) at the 56 and 76-fathom levels but at the 96 and 116-fathom levels Harriett's lode faults the caunter. The Caunter lode passes from killas into granite. It has an underlie of 15 deg. S. and a bearing E. 4 deg. S.¶ This lode produced considerable quantities of copper ore to the 125-fathom level; but recently it was intersected in the granite by the 220-fathom cross cut driven south from the Old Sump shaft and at that depth is tin bearing.

Particulars of other Caunter lodes are given in the following table:—

Mine.	*Caunter Lode.*	*Bearing.*	*Underlie.*	*Remarks.*
		Deg.	Deg.	
Cook's Kitchen	South Caunter	E. 20 N.	40 S.	Contained tin and probably copper ore.
	Middle Engine lode	E. 5 N.	15 N. to 40 N.	Branched from Chapel's lode at the deep adit and was productive in copper ore until it changed its underlie to 40 deg. N. at the 52-fathom level.

* De la Beche, p. 365. † *Min. Cornub.*, 1778. ‡ p. 19. § p. 105.
|| Table L., Henwood quotes the authority of R. W. Fox. *Phil. Tr.*, 1830.
¶ Henwood, Table L., states that the bearing is E. 11 deg. S.

Mine.	*Caunter Lode.*	*Bearing.*	*Underlie.*	*Remarks.*
		Deg.	Deg.	
Carn Brea -	Druid Caunter	E. 20 S.	Nearly vertical	An ore-bearing lode from adit to 50-fathom level.
	Vigur's lode	E. 20 S.	Nearly vertical	South of Druid lode, to which it is connected by short branches. Contained copper ore to the 105-fathom level and then tin ore.
Camborne Vean		E. and W.	S.	Probably copper.
West Roskear		?	?	Caunter branched from main lode at about 12-fathom level. Both lodes contain lead, blende, copper and iron pyrites, and tin.
Great North Seton				Branched off from the main lode at the 70-fathom level.
South Wheal Seton		E. and W.	15 N.	Branched off from main lode in deep levels.
Wheal Seton -	North Caunter lode	E. and W.		Worked upon in North Roskear and East Wheal Seton. It contains copper and iron pyrites. (Harry Tilly, "Particulars of a Thermal Spring at Wheal Seton." *Miners' Assoc.*, 1873.)
	South Caunter lode		45 N.	Contains some tin ore.
North Wheal Crofty				A Caunter lode in west end of mine of no value.
South Crofty -	Reeves' Caunter lode	E. 3 S.	10 N.	Contained copper ore to the 90-fathom level. Recognised in North Roskear and Wheal Seton.
	Longclose Caunter	E. 30 S.	Nearly vertical to N. 13.	Vertical to the 35-fathom level. Copper ore abundant to the 115-fathom level. (Henwood, Table lvi.)
	Copper Tankard lode	E. 24 S.		Contains copper, zinc ores, and iron pyrites.
	Trevenson lode	E. 2 S.	14 to 40 N.	Yielded copper ore. (Henwood, Table lvi.)

Mine.	Caunter Lode.	Bearing.	Underlie.	Remarks.
		Deg.	Deg.	
Wheal Crofty -		E. 25 S.	8 to 25 S.	Contains copper, lead and zinc ores, and iron pyrites. (Henwood, Table lv.)
Gustavus -		E. a few degs. N.	S.	
Wheal Tehidy		E. and W.	N.	Copper and iron pyrites.
East Pool -		E. 24 S.		Branched off from the south of Pryce's lode. A Caunter at the 170-fathom level in granite is a brecciated lode, contains tin and other minerals, with later vein of chalybite. This lode is being worked.
	Middle lode	E. 24 S.	S	Copper to the 70-fathom level.
Park an Bowan (Roskearnoweth)				(Part of North Roskear) contains copper and zinc ores.
Wheal Harriet		E. and W.		Copper ores. This mine is in granite.
Great Condurrow				Caunter at 10-fathom level contained copper ore.
West Basset -		E. 20 S.	S.	Contains copper and tin. It intersects Williams' lode.
Wheal Basset -	Caunter		20 N	Faults the Great Flat lode.
Wheal Gorland				Lodes counter to one another.
South Wheal Hawk			2 or 3 N	Contains copper. It intersects the South Wheal Hawk copper lode. (Thomas, p. 43.)
East Wheal Chance			2 or 3 N.	The Caunter lode intersects the main lode which underlies south and faults it 12 feet. Both contain copper. (Thomas, p. 37.)
Wheal Basset and Grylls				A Caunter lode 5 feet wide containing tin ore.
Crenver (and Wh. Abraham)				A Caunter lode intersected and heaved by the Great lode 70 fathoms. (Carne, p. 98.)

Mine.	*Caunter Lode.*	*Bearing.*	*Underlie.*	*Remarks.*
		Deg.	Deg.	
Herland - -	Fancy Caunter lode	E. 35 S.	8 to 18 S.	(Henwood, Table xxiv.)
North Downs -		E. 28 N.	7 to 10 N.	Contains copper pyrites. Forms a junction with the Tenpenny lode and is with it for 8 fathoms. (Henwood, Table lxix.)
United Mines -	Bawden's South lode		S. 10 to 24	Two lodes have an east and west bearing but are not called Caunters. Both contain copper ores. (Henwood, Table lxi.)
	Nicholls' Branch		S. 12 to 30	
	Caunter lode	N.E.		(Carne).
Killifreth -		E. 34 N.		The main lode has a nearly E. and W. bearing and the Caunter branches off from it on the north side.

The foregoing list is far from complete, and there are probably errors in the few details which it has been possible to collect. On the whole the Caunter lodes are far more common in the killas than in granite, and although some of them contain tin ore, they more generally contain copper or other ores. As a whole Henwood's statement that "Caunter lodes have no distinctive character but that of direction" is true.

VI. Intersection of Lodes.

The question here concerned is largely that dealing with faulting, and whether or not there is any justification for the view that the lode fissures were formed successively by distinct epochs of movement. The information of the precise mineral phenomena of the intersections of lodes is very meagre, but in view of the diverse opinions of different writers* the case requires a very careful examination of the facts. The question is complicated by the probable processes of secondary concentration of some of the ores in the lodes, their unequal mineralisation, and by the movements that have taken place in the lodes long after they were formed. The facts recorded by early writers must sometimes be treated with caution; thus there are somewhat disturbing state-

* In 1778 Pryce classified the lodes under twelve heads (*Mineralogia Cornubiensis*, p. 88). In 1822 Carne divided the fissures into eight successive epochs of formation (*Trans. Geol. Soc. of Cornwall*, vol. ii., pp. 85-119). In 1897 Mr. Collins classified the lodes under nine heads, each representing a distinct epoch of movement (*Journal Roy. Inst. Cornwall*, 1897, p. 195).

ments in one of Carne's papers, in which it is said that "in some copper lodes tin is so plentiful in some parts as to give them, for a short space, the appearance of tin lodes."* And, again, "it is considered a favourable symptom to find, on the back (of the 'oldest east and west lodes') tin ore."† Carne states that "it appears probable that previous to about A.D. 1700, the copper ore produced in Cornwall was principally, if not wholly, from tin mines, or at least from mines originally wrought for tin."‡ Richard Thomas says that the "Chacewater lode at Wheal Daniell is called a tin lode; at Chacewater Mine, a tin and copper lode; and at Treskerby a copper lode."§ Phillips states that the old miners frequently worked a lode for copper, entirely ignoring the presence of tin ore, considering it to be not worth working, or else thinking the lode was of no more value after the copper ore had been extracted.‖ There are many cases where a number of lodes are proved in depth or in their direction of strike to be really branches of one lode, although each is treated by the miners as a separate lode and called by a special name. In the following are a few particulars of the intersections with one another of what appear to be independent fissures :—

Cook's Kitchen Mine.—The Great lode, which has a southerly underlie, intersects and heaves Toy's lode, which underlies north, to the extent of 18 fathoms at a depth of about 105 fathoms below adit. Above this place the Great lode was only copper bearing, but the part of the lode between the intersected portions of Toy's lode contains both copper and tin. Below the intersection the Great lode only contained tin ore. Thus it contained no tin above the intersection and no copper below.¶ The Great lode is that which is known at the present time as Dunkin's lode. Exploration in the deeper parts of the lodes since Carne made the above observations shows that copper occurred in Dunkin's lode to the 222-fathom level. Thomas states that Toy's lode contains both tin and copper ores and that it crosses the Great lode at the 90-fathom level.** Henwood says that the junction consisted of "a mass of earthy red iron ore, quartz and vitreous copper ore 10 feet wide. They continue mixed on the line of Dunkin's lode for 9 fathoms" after which there is black and vitreous copper ore, crystallised red oxide of copper, and some tin ore.††

Wheal Basset.—The intersection of the Great Flat lode by the numerous more or less perpendicular lodes which heave it is characterised by a great widening of the Flat lode near these places. The lodes which fault the Great Flat lode contain mainly copper ore, but copper ore also occurred in the upper part of the Great Flat lode itself, while some was also only recently taken from it at the 250-fathom level in Wheal Basset. The tin ores in this mine are mainly obtained from the Great Flat lode, but tin also occurs in smaller quantities in the lodes which intersect it. The lines of intersection are not distinct, but in West Wheal Frances (further west) a copper lode containing some tin ore is stated to have actually passed through the Flat lode as a distinct vein.

North Roskear and Wheal Crofty.—The Engine lode is possibly traversed by the Caunter lode which underlies south. The intersection

* Carne, p. 103. † *Op. cit.*, p. 93.

‡ "Copper Mining in Cornwall." *Tr. R. G. S. Cornwall*, vol. iii., 1828, p. 44.

§ Thomas, p. 20.

‖ "On the Veins of Cornwall." *Tr. Geol. Soc.*, vol. ii., 1814, p. 122.

¶ Carne. ** Thomas, p. 33. †† Henwood, Table li.

of the Cannter lode with the South lode, which has a variable underlie, is simply a confused lode, and at a lower level these lodes are together for 7 fathoms with no sign of a heave. They all carry copper.*

South Condurrow.—The Engine, Middle and West Basset lodes, which are more or less vertical, all heave the Great Flat lode. All of them contain tin and copper, but the Great Flat contains very little copper and the other lodes not much tin.

South Frances Mine.—The Basset lode and two other lodes heave the Great Flat lode between the 134 and 205-fathom levels. The Basset lode underlying north intersects one of the copper lodes which underlies south. They all contain tin and copper ores. The Great Flat contains but little copper, while the other lodes contain more copper than tin.

South Crofty.—The Middle lode drops from the south wall of Pryce's lode into the North lode. The lodes cannot be distinguished at the junctions and are of similar composition, containing tin and copper ores.

Treskerby.—The Flat North underlying copper lode crosses the north underlying Chacewater lode at the 60-fathom level. The Chacewater lode in Chacewater Mine contains tin and copper; in Wheal Daniell it is called a tin lode.†

United Mines.—The South lode and the Great lode (in the Ale and Cakes part of the mine) intersect each other at the 170-fathom level. Both underlie north and contain copper.‡ The Mundic lode underlying north intersects, but does not heave Bawden's lode, which underlies south. Both lodes contain tin and copper.§ The Cargruel lode, containing both tin and copper, traverses the Rapsey copper lode.||

Wheal Gorland.—Dennis's lode, which is a vertical copper lode, intersects Green's lode, which underlies north and contains tin and copper.¶

Wheal Unity.—The Solid tin lode underlies north and forms a junction with Francis copper lode, which underlies south. The lode so formed carries both tin and copper, and is known as Green's lode in Wheal Gorland.**

Carzise Mine.—The Caunter lode joins the Carzise lode and they continue as one lode for 20 fathoms and then separate. Both carry tin and copper and underlie south.††

East Wheal Chance.—See p. 226.

Poldice.—The Great ore lode underlying north and containing copper intersects and heaves to the extent of about two fathoms the Poldice tin lode and the Bissoe tin lode, which underlie south.‡‡

Scorrier Mine.—Two copper lodes underlying north are intersected by a Caunter lode underlying north and containing copper. The Caunter is the same as that seen in East Wheal Chance.§§

Wheal Hawke.—The Wheal Hawke copper lode underlying south intersects the tin lode which underlies north. Similarly, the Pendarves copper lode crosses a south underlying tin lode in Wheal Messar.||||

Nangiles.—Two copper lodes heave a tin lode.¶¶

Dolcoath.—See p. 140.

East Wheal Crofty.—The Longclose main lode intersects the Longclose Caunter lode at the 30-fathom level. At the 54 and 65-fathom levels the main lode heaves the Caunter lode 3·5 and 5·5 fathoms respectively. Both lodes underlie north and both contain copper and zinc.***

* Henwood, Table lv.
† Thomas, p. 20.
‡ *Op. cit.*, p. 49.
§ Henwood, Table lxi.
|| Carne.
¶ Thomas, p. 56.
** Thomas, p. 65.
†† Henwood, Table xli.
‡‡ Thomas, p. 40.
§§ *Op. cit.*, p. 42.
|||| *Op. cit.*, p. 57.
¶¶ Carne, p. 88.
*** Henwood, Table lvi.

TING TANG.—The middle lode unites with the main lode westwards and forms one lode with it. Both lodes contain copper and underlie north.*

CONSOLIDATED MINES.—Glover's and Kitto's lodes both underlie south and intersect Paul's lode which underlies north; all contain copper. Taylor's and Tregonning's lodes unite eastwards.†

SOUTH WHEAL TOWAN.—The Slide lode is thrown up 25 fathoms by the South lode. Both are copper lodes.‡

The above list, together with that of the Caunter lodes, includes the cases upon which systems of classification according to the different ages of lodes have been based. It appears that in these instances the intersecting lodes do not differ from each other, except in a few cases, in the actual minerals they contain. In some lodes, however, copper predominates, while in other lodes tin ore is more abundant than copper. The case at Cook's Kitchen Mine (page 144) shows how easy it is to be misled as to the precise meaning of these intersections. In Poldice it appears that a tin lode is heaved by a copper lode. On the whole those lodes containing much more copper than tin sometimes intersect those containing more tin than copper. Joseph Carne§ endeavoured to classify the lodes into distinct systems, but the data upon which he based his classification were incomplete. Thus he refers to the Dolcoath lode as being one of the "oldest east and west copper lodes," whereas it is known at the present time that in depth it is an exceedingly fine tin lode with no copper in it.

Before the lodes can be classified in this manner it must be shown that there are two or more distinct fissure systems, each of which contains characteristic minerals, separating it in some way from the others. The formation or re-opening of a fissure giving rise to a lode is not necessarily followed immediately by infilling of minerals.

VII. FAULTING BY LODES.

De la Beche pointed out long ago that most of the lodes are faults. The evidences of faulting are based upon direct observation, which can be classed under three heads: (1) Dislocation of the walls of the lode; (2) Form of the fissure; (3) Brecciation of the walls of the fissure.

On account of the similarity in dip and strike of the lodes and elvans it is only in a few cases that the elvans are clearly seen to be faulted by the lodes which cross them.

At Herland Mine (Gwinear) an elvan is heaved six feet by a Caunter lode.‖ Another elvan in the same mine is thrown some fathoms by a lode (*op. cit.*). At Duffield Mine there is a similar instance.¶ The Great Flat lode, south of Camborne, is faulted by several more or less vertical lodes in South Condurrow, South Frances, West Basset, and Wheal Basset. At Wheal Basset the

* Henwood, Table lx. † *Op. cit.*, Table lxii. ‡ *Op. cit.*, Table lxxii.
§ Carne. ‖ Henwood, Table xxxiv. ¶ *Op. cit.*, Table xxxvii.

Flat lode is heaved 20 fathoms by the Old lode.* In Camborne Vean Mine the granite is heaved 20 fathoms by the lode, and in Dolcoath the hanging wall of the Caunter lode is lower than the footwall. At South Crofty Mine the granite is faulted down southwards by Pryce's lode to the extent of 9 fathoms. The sheet-like intrusions from the granite in Cook's Kitchen Mine and Tincroft are dislocated by the Highburrow and other lodes.† The granite is faulted (10 fathoms) at Wheal Beauchamp by a lode,‡ and at Tresavean§ and Wheal Trannack.‖ Cases where one lode faults another are common. At South Wheal Towan the south underlying lodes are dislocated by the north underlying lodes to the extent of 25 fathoms (see page 146).

The form of the fissure frequently shows that faulting has taken place, as the infilling is often made up of alternate wide and narrow parts produced by the movement of the walls of an irregular crack along one another. Any of the larger lodes exemplify this.

Brecciation of the lode materials indicates crushing by movement of the walls either during dislocation or by vibration, such as those arising from earthquake shocks. "Fragments of slate cemented by quartz and yellow copper ore" were obtained from the principal lode of the Consols Mine, Gwennap. Angular pieces of slate cemented by yellow copper ore were found at the United Mines, Gwennap. At Wheal Jane (Helston) similar veinstones occur. At Binner Downs Mine (Crowan) angular portions of slate, yellow copper, and zinc blende cemented by pearl spar or carbonate of iron occurred.¶ Brecciated veinstones from the deep levels of the lodes can be identified in East Pool, South Crofty, Dolcoath, and Wheal Basset. Slickensides occurring in a lode already supposed to be a fault are confirmatory evidence. "Slickensides" may, however, be produced by the squeezing of a soft substance such as moist clay between hard walls, or by a vibratory movement of the walls upon one another, or it has been suggested that etching of the walls by corrosive gases may produce the appearance of a slickenside. In Cook's Kitchen Mine the footwall of the Highburrow lode at the 270-fathom level is a hard granite scratched up and down for several fathoms. At the 210-fathom level in the main lode of Dolcoath, on the west of the North Valley shaft, there are horizontal striations. Numerous slickensides occur also in Wheal Uny.** Slickensides on iron and copper pyrites occurred in the walls of lodes in Great Wheal Fortune, South Crofty, and Consolidated Mines.†† In conclusion, it may be stated that movements appear to have taken place in the plane of the lode both before and after mineralisation, and of those lodes

* J. Maynard, "Remarks on Two Cross Sections." *Rep. Corn. Poly. Soc.*, 1871.

† Thomas, p. 43. Henwood, Table li. and p. 60.

‡ Henwood, p. 199. § *Op. cit.*, p. 71. ‖ *Op. cit.*, p. 197.

¶ De la Beche, p. 323.

** R. H. Thomas, "Some Observations on the Great Flat Lode in Wheal Uny." *Rep. Corn. Poly. Soc.*, 1886, p. 184.

†† Henwood, p. 181.

in which both can be shown to have occurred the principal are found at the margin of the granite, which is a position of structural weakness, and may be described as the focus of the metalliferous area. It is a position very favourable to the production of breccias. It is more than probable that the largest ore lodes are generally to be found at the edge of the granite where the lodes are parallel to the granite margin.

Lodes in which the Faulting is Insignificant.—Mr. Hill states* that in the parish of Wendron there is "an extremely attenuated set of mineral veins which have been extensively worked for tin." He traces a connection between these fissures and the E.N.E. system of joints (toughway joints of the granite), and concludes that they originated in the continued operation of the same stress with which the intrusion of the granite is connected. It is not improbable that the tin deposits of Wheal Lovell and East Wheal Lovell and many other mines afford some instances of this nature.†

In many cases the lodes of this region each consist of a series of close parallel cracks. The intervening layers of country rock have been so completely changed, and the fissures themselves so obliterated by the action of the vapours which once traversed them, that the original structure of the lode is altogether lost, and may have the appearance of a massive fissure infilling. Sometimes there are two or more systems of cracks intersecting each other at a narrow angle, and seeming to form conjugated systems such as those referred to by Daubrée. "But," as Mr. Hill points out, "when the granite is followed into the districts of Redruth and Camborne, the magnitude of the fissure lodes and elvans have reached their maximum, and the marginal zones of the granite constitute the heart of the mineral area."‡

With regard to the origin of the jointing in its relation to lode fissures, Professor Crosby's hypothesis that parallel jointing is due to earthquake movements is one worthy of consideration.§

VIII. Trend of the Lodes.

The metalliferous fissure veins or lodes in any particular part of this district, in common with the elvan dykes (and "toughway" joints of the granite), have a certain more or less definite bearing which varies slightly for each locality from the bearing common to the whole. Henwood‖ states that the mean strike of the lodes in the Camborne district is E. 20 deg. N., and that in the Redruth district it is E. 22 deg. N. The mean strike of all the lodes in any particular locality is, however, not the same as the mean strike of the principal lodes; in Camborne, for instance, the mean bearing of

* J. B. Hill, R.N. (H.M. Geol. Survey), *Summary of Progress*, 1903, p. 31.

† See "Tin Deposits of East Wheal Lovell," by C. Le Neve Foster. *Tr. R.G.S. Cornwall*, vol. ix., 1876.

‡ *Summary of Progress*, 1902, p. 31.

§ W. O. Crosby, *Proc. Boston Nat. Hist. Soc.*, 1882, vol. xxii. *The American Geologist*, vol. xii., 1893.

‖ p. 250.

the principal lodes is E. 30 deg. N. There are, therefore, certain lodes which have a bearing differing from that of the majority; and in Camborne there is a marked series of lodes having a bearing nearly E. and W. called Caunter lodes. These lodes "have no distinctive character but that of direction,"* and are comparatively few in number.

The following tabular statement is an attempt to give for each locality the mean bearings of those lodes that have the same general trend:—

Lodes.	Bearing.	Remarks.
Camborne District.—Dolcoath, &c., and the lodes on the north.	E. 30 deg. N.	Lodes along the margin and on the north of the Carn Brea granite, excluding Caunter lodes.
Lodes in the granite on the south of above, excluding the Great Flat lode.	E. 32 deg. N.	Great Flat lode. (From South Condurrow to West Frances E. 31 deg. N. From West Frances to South Carn Brea E. 35 deg. N. From Wheal Uny eastwards 18 deg. N.)
Redruth District.—Round the margin of the Redruth granite.	E. 22½ deg. N.	The lodes on the northern margin have a bearing greater than this number; those on the south less. Some have a nearly E. and W. bearing.
District on the north of the Redruth granite.	E. 21½ deg. N.	The bearings vary from E. 15 deg. N. to E. 35 deg. N. Some lodes run nearly E. and W., and are not included.
Carnmenellis granite. Round the N. and N.E. margin.	E. 30 deg. N.	The bearings vary from E. 16 deg. N. to E. 36 deg. N. the latter being the Tresavean main lode, the former those lodes on the north and north-west of Tresavean.
Gwennap District.—Between St. Day and Twelve Heads.	E. 20 deg. N.	Some of the lodes not included bear nearly E. and W.; others bear E. 30 deg. N. to E. 40 deg. N.
District between Twelve Heads and Newbridge.	E. 34 deg. N.	One lode, at least, has an E. and W. bearing, and is not included. Lead lodes not included.
Wendron District.—Southern part of Carnmenellis granite	E. 36 deg. N.	The lodes vary in direction from E. 15 deg. N. to E. 53 deg. N. The latter are round Garlidna and Halabezack district. There appear to be several series of lodes corresponding with directions E. 5 deg., 17 deg., 28 deg., 35 deg., and 48 deg. N.
Porth Towan lodes.	E. 20 deg. N.	Some lodes not included strike nearly E. and W.

IX. Underlie of the Lodes.

As a rule, the principal lodes underlie north, and in this their behaviour is similar to that of the elvans.

* Henwood, p. 253.

Taking the Camborne district first, and traversing the district from north to south, the following general average underlie of the principal lodes is obtained.

The most northerly series of lodes in the Camborne district is that extending from Wheal Tolgus (on the east) through West Wheal Tolgus westwards. Situated entirely in the killas, the average underlie is from 26 deg. to 30 deg. N. The next series, on the south, includes the lodes of the Seton Mines through to North Pool and South Wheal Tolgus; the average underlie is 40 deg. N., but the lodes on the west are flatter than those on the east.

The next series includes the lodes of the Roskear Mines, South Crofty, East Pool, and Wheal Tehidy. In South Crofty and East Pool the lodes pass into granite in depth. The average underlie is from 20 deg. N. to perpendicular, but some lodes underlie south.

A single lode lying between the last series and the next is known in Dolcoath as the North Entral lode, and eastwards as the North Tincroft lode. It underlies N. 34 deg. (average).

The next series is that situated along the margin of the Carn Brea granite, and extends from West Stray Park, through Dolcoath, Cook's Kitchen, Tincroft, and Carn Brea. The lodes vary from vertical to S. 18 deg.; but in the deep levels of Dolcoath, over 300 fathoms in the granite, the underlie is S. 45 deg. Numerous lodes in the upper levels of these mines underlie north. South of this series is a lode situated in granite extending from Carn Camborne to Wheal Providence, and it underlies a few degrees north to vertical. The lodes from Great Condurrow to South Dolcoath Mine underlie a few degrees S. Along the southern margin of the Carn Brea granite is a series of lodes situated mainly in granite extending from South Tolcarne through South Condurrow, West Francis, West Basset, and Wheal Basset (in killas). These lodes are more or less vertical, but some underlie north and others south. The Great Flat lode, which belongs to this series, is exceptional, and has an average southerly underlie of 51 deg., but is steeper on the east and flatter on the west.

There are a few lodes extending from Grillis to South Wheal Basset, situated in granite. The underlie is a few degrees to the north.

The district from Scorrier Gate to the United Mines in Gwennap can be dealt with in a similar manner as follows:—

The lodes of Wheal Mary and Little North Downs intersect each other, some lodes underlying south and others underlying north. They appear to follow no particular direction as regards underlie. Some of the lodes of New Treleigh Consols, Wheal Peevor, and North Downs underlie north at about 19 deg., but some underlie south or are vertical. The main lodes of Treskerby and Great Wheal Busy (Chacewater Mine) underlie north from 34 deg. to 40 deg., but some lodes underlie south. The lodes of Killifreth underlie north at 58 deg. or less. The Unity Wood series underlies north. The Wheal Gorland lodes underlie north or are perpendicular. The lodes from West Wheal Damsel to the Consolidated Mines underlie north from 20 deg. to 25 deg. There are numerous south underlying branches in the Consolidated Mines. The lodes from Ting Tang, through the United Mines, Wheal Clifford, and Nangiles to Wheal Jane underlie north from 20 deg. to 65 deg. A few lodes in Nangiles are nearly perpendicular.

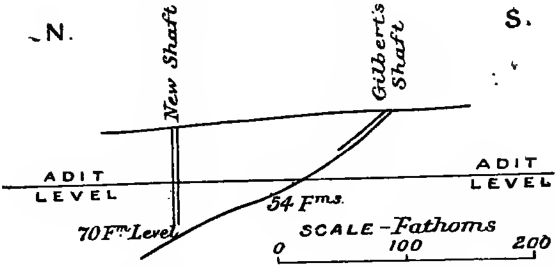
"FLAT"* LODES.—There are many cases of lodes underlying at about 45 deg., but in a few cases the lodes approach more nearly to a horizontal than to a vertical position. The following examples indicate those of low hade:—

At West Wheal Seton (on the north of Camborne) the underlie of the lode (which is accompanied by an elvan) is 58 deg. N. At Wheal Jane the main lode underlies north at about 65 deg. (Fig. 17.) At Killifreth the middle lode underlies north at 58 deg. (Fig. 18.) The Great Flat lode

* The term "Flat Lode" is commonly applied in Cornwall to a lode with a characteristic low hade.

(along the southern margin of the Carn Brea granite) is the only south underlying Flat lode. At South Tolcarne its underlie is 80 deg. S. (10 deg. from the horizontal), but eastwards the lode becomes gradually steeper, until at Wheal Uny it is 45 deg. S. There are several places in which the lode is almost vertical, but only for short distances. At Wheal Squire the Flat lode underlies N. 54 deg.* At Wheal Peevor the Flat lode underlies north at 53 deg. There are also Flat lodes in Wheal Music, United Hills, Wheal Busy, &c.

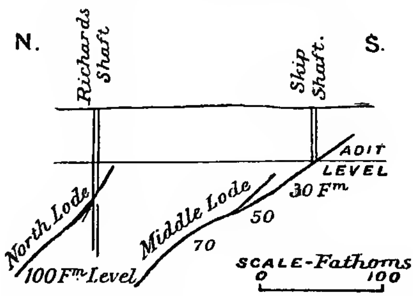
FIG. 17.—*Wheal Jane.*



THE RELATIVE UNDERLIE OF LODES AND ELVANS.—There are a great many cases in which the lodes underlie in the same direction as the elvans in their vicinity.

The flat, north underlying lode in the Seton Mines, on the north of Camborne, is contiguous to an elvan. The lodes of Dolcoath Mine in the deep workings are associated with elvans. Some parts of the Great Flat lode in Wheal Basset are mineralised elvan, which underlies south at about the same angle as the lode. At Wheal Wentworth (near Redruth) an elvan underlies in the same direction as the lode. At North Wheal Crofty a

FIG 18.—*Killifreth Mine.*



north underlying elvan is intersected by north underlying lodes which are slightly steeper. In the Clifford Amalgamated Mines two north underlying elvans are intersected by slightly steeper north underlying lodes; and in Nangiles, Treskerby, Wheal Busy, Killifreth, and Wheal Jane the lodes and elvans are more or less parallel or occupy the same fissure. At Copper Hill an elvan underlies north with the lode. At Wheal Moyle Ting Taug, an elvan underlies northwards towards the granite, and is intersected by north underlying lodes which are slightly steeper. At Wheal Jennings (Parbola-Gwinear), Bissoe Bridge (near the United Mines

* J. Carne, "On the Veins of Cornwall." *Tr. R.G.S. Corn.*, vol. ii., 1822, p. 98.

Gwennap), Chacewater Tin and Copper Mine* and Wheal Unity,† much of lode material is only mineralised elvan. Thus, many of the lodes underlie in the same direction as the elvans, and either at the same angle or more steeply.

The angular difference between the amount of underlie of the lodes and elvans occurring in the same mine in a few selected cases is as follows:—

In West Stray Park Mine the difference in underlie of the elvan and lode is about 25 deg., in Wheal Clifford from 35 deg. to 50 deg., in the United Mines about 30 deg., in Ting Tang Mine about 20 deg., in Wheal Emily Henrietta (near Tolvaddon) about 25 deg.; in all these cases the elvans and lodes underlie towards the north and are in killas, and in no case is the elvan steeper than the lode. Similar differences are observed in the granite, but where, as in Dolcoath, the lodes and elvans are south underlying, the elvan is steeper than the lode or is parallel to it.

Cases in which lodes underlie in a direction opposite to that of the elvans are not so numerous or striking.

The Engine lode at East Pool Mine is a steep south underlying lode, and intersects an elvan which underlies north. Similarly, in Cook's Kitchen Mine the main lode (Highburrow) underlies southwards into the granite, and intersects an elvan which underlies northwards. Finally, there are numerous cases where the lodes of a mine underlie in different directions and, consequently, intersect each other. Thus: at Little North Downs Mine, one set of lodes underlies north in the same direction as an elvan, while another set underlies south. Similarly, at Chacewater Mine, the ore-bearing, north underlying, elvan is intersected by south underlying lodes.

X. Length of the Lodes.

The length of a lode is the length of a more or less continuous fracture which may be subject to the irregularities of ordinary faults. Most of the lodes have not as a rule been completely explored from end to end, owing to their poverty or other causes; but the lodes of one mine can be frequently identified in a neighbouring mine into which they pass. "Whether explored horizontally or as they descend in depth, they are seen often to be wavy and irregular, to go off from and return to their usual direction, and to present so many anomalies, that whilst on a map we may be obliged to take a straight line as an average, the real course is usually such as not only to complicate the workings but to make us slow to accept some of the brilliant theories which have connected lines of fissures with actual dates asserted to be discoverable in the elevation of mountain chains."‡ In a general way, however, the important lodes, whether as single fissures or mineralised zones, have been traced for considerable distances across the country.

The Great Flat lode extends continuously from South Tolcarne, through South Condurrow, West Francis, West Basset, South Carn Brea, and Wheal Uny to Cal Downs (on the western margin of the Redruth Granite), a distance of 3½ miles. It becomes steeper as it goes eastwards, and so loses its chief peculiarity, making it a matter of difficulty to identify it in that direction. The Dolcoath main lode extends from Carn Brea Mine,

* J. Carne, "On Elvan Courses." *Tr. R.G.S. Corn.*, 1818, vol. i., p. 104.
† Brenton Symons. "A Sketch of the Geology of Cornwall," 1884.
‡ Warington Smyth, F.R.S., "Physical Phenomena connected with the Mines of Cornwall and Devon." *British Assoc. Rep., Plymouth*, 1877.

where it is known as the Highburrow lode, through Tincroft, Cook's Kitchen, Dolcoath, Camborne Vean and West Stray Park, to near Ramsgate. Total length nearly 3½ miles. The Carn Camborne main lode extends from Kellivose through Carn Camborne and Wheal Providence to Wheal Druid, a distance of over 2½ miles. The Wheal Briggan main lode extends from Wheal Mary, on the west, through North Downs and Wheal Briggan to East Downs. Distance 2½ miles.* The Great Wheal Busy lode has been traced from Wheal Daniell (on the east) through Great Wheal Busy, Scorrier Old Mine, Treskerby to Cardrew† and possibly runs into Treleighwood Mine. In the United Mines the old lode has been traced from Camborne Parish through Carnkie to Baldhu, a distance of 7 miles.‡

No information is forthcoming of the way in which a lode dies out in the direction of strike, since if the lode is poor it has been abandoned; and, as William Phillips states, "the most experienced miner never satisfactorily witnessed the termination of a vein either on the east or west."§ Where a lode in killas is coincident with the cleavage, it probably dies out gradually along these planes. Mineralised joints in granite will die out into a mere line of rifting.

XI. Breadth of the Lodes.

The breadth of a lode includes the width of the infilled fissure and the altered rock on each side of it. As both these factors are liable to considerable variation it is almost impossible to determine what is the true width of any single lode. But by means of a number of measurements, Henwood‖ found the mean width of the lodes in the Camborne district to be 3·68 feet, and in Redruth 3·36 feet; and generally that the width of the lodes in slate is greater than that in granite. He also noted that, on the whole, the lode containing both tin and copper ores are wider than those containing copper only. Since Henwood's time the workings have been carried to a much greater depth, and the information so obtained casts considerable doubt on the conclusions he arrived at, more especially since many of the lodes are not single fissures.

A few examples will illustrate the difficulties in the way of any attempt to calculate an average for the width of the lodes.

Dolcoath.—The lodes where principally worked vary in width from a mere parting to 20 feet, but the average is 3 or 4 feet.¶ The widest parts of lodes occur principally where there is an abrupt change in the strike of the lode. From the 200 to the 300-fathom level (in granite) the lode varies in width from 1 to 9 feet. At the bottom of the mine, near the 490-fathom level, nearly 300 fathoms in the granite, the lode consists of a hard breccia, 42 feet in width. The junction formed by the Main and South Entral lodes is 60 feet wide. The South lode—which is a branch of the main lode—varies from 6 inches to 2 feet in the upper levels. The Silver lode is about 2 feet wide. The Caunter lode varies from 6 inches to a foot.

The Great Flat Lode.—The part of the lode left standing in Wheal Granville is 1 foot to 8 feet in thickness, and in South Condurrow the tin-bearing part is 5 or 6 feet in breadth, but the total width of the lode including the barren capel in either wall, is 12 to 20 feet. In West Wheal Basset the lode and altered country rock at the 140-fathom level are

* Thomas, p. 30. † *Op. cit.*, p. 32.
‡ J. Carne, "On the Veins of Cornwall." *Tr. R. G. S. Corn.*, vol. ii., p. 96.
§ "On the Veins of Cornwall." *Tr. G. Soc.*, vol. ii., 1814, p. 113.
‖ p. 243.
¶ Josiah Thomas. *Journ. Roy. Inst. Corn.*, 1868, vol. iii., p. 192.

together 40 to 50 feet in thickness.* In Wheal Uny the same lode varies from 4 to 10 feet in thickness, and in one place near a cross course is 72 feet wide.†

MISCELLANEOUS LODES.—In Tincroft Mine, on the north of the Carn Brea granite, some parts of the Highburrow lode are 3 or 4 feet wide, while other parts are 30 to 40 feet. The Engine lode at North Roskear varies from 1½ to 18 feet. In Wheal Vor the main lode varies from 3 to 30 feet. The Bor lode in Polladras Downs Mine varies from 1 inch to 4 feet.‡ In Nangiles the main lode reached a maximum width of 30 feet.

OBSERVATIONS ON THE WIDTH OF LODES.—If the original fissure in which a lode is formed is irregular, the relative displacement of its walls by faulting results in the formation of open and closed parts as was shown by De la Beche,§ Le Neve Foster,‖ and other writers. During the act of dislocation the walls of the fissure are crushed or ground together so that the original walls are obliterated. In this manner the fissure becomes largely filled with breccia. These breccias may also originate in the swift vibratory movements accompanying earthquake shocks, or may result from direct pressure without faulting.

Again, the width of lode is largely determined by the extent of the alteration in the vicinity of the fissure by active agents contained in solutions traversing the fissure. It will be seen, then, that in nearly all cases where the width of a lode is given it much exceeds the amount of opening in the original fissure. In this way the walls of those parts of a fissure which have afforded a passage for mineral solutions for a lengthened time must (other conditions being equal) be altered more completely, and for a greater distance on either side than in a case where access of solutions was only limited.

Finally, every movement, which is not one of shearing under great lateral pressure, serves to further increase the width of the fissure, so that in this manner a lode is always tending to increase in size. Where, as is often the case, the lode consists of a series of close parallel joints or cracks, the width of the lode varies considerably, according to the number and proximity of the cracks.

XII. VEINSTONE OF THE LODES.

In hand specimens the veinstones in any particular lode are considerably varied. Broadly speaking, the miner recognises certain types to which special names are given (see page 136). The miners' terminology, although rough and ready, is expressive enough. The characteristic veinstones of any part of the lode area vary almost imperceptibly in passing from one place to another, owing to the preponderance of different minerals over one another in different parts of the district. Certain types of

* C. Le Neve Foster, "On the Great Flat Lode." *Q.J.G.S.*, 1878, vol. xxxiv., p. 640.

† R. H. Thomas, "Some Observations on the Great Flat Lode." *Rep. Corn. Poly. Soc.*, 1886, p. 184.

‡ Henwood, p. 240. § Geological Report previously cited.

‖ "Remarks upon the Tin Deposits of East Wheal Lovell." *Trans. R.G.S. Corn.*, vol. ix., 1876.

veinstone are regarded as good or bad signs of the value of the lodes. A soft or "plumb" lode containing quartz and chlorite, or a little clay or prian is supposed to be a good lode. The hard blue-black rock (schorl rock) which is commonly met with, especially in the deeper parts of the lodes, is a good sign, particularly if it is brecciated, although tin ore may only occur in it in small quantities. The schorl rock of a somewhat lighter blue colour, frequently modified by the presence of kaolin, rendering the rock more or less pulverulent, and especially if associated with chlorite, is an excellent indication of a good lode. The presence of oxide of iron, or the existence of cavities or vugs, are supposed to be indications of a good lode. A quartz (sparry) vein, unless accompanied by other minerals such as peach, chlorite, &c., is considered valueless as an indication of the presence of ore.

William Phillips* makes mention of the miners' saying that "Black Jack rides a big horse," from the fact that a lode containing blende in the upper part is often rich in copper in depth; an instance of this being Wheal Towan.

Microscopic Structures of some Tin Stones. (Plate XII.)

The microscopic structure of the veinstones of the Camborne area, from material collected at Dolcoath, Wheal Basset, South Crofty and Carn Brea, was described by Dr. Flett in the Summary of Progress of the Geological Survey for 1902 (pp. 154–159).

The descriptions that follow illustrate the micro-photographs depicted on Plate XII.:—

Fig. 1.—Veinstone from Carn Brea Mine. The material is a breccia consisting mainly of quartz, tourmaline, and cassiterite. In the tissue sketch over the plate the cassiterite is represented by (1), cassiterite and tourmaline needles by (2), quartz by (3). (E. 3,601).

Fig. 2.—Carn Brea Mine, 300-fathom level. The slide shows large crystals of tin ("Zinngrauper,") with usual zonary banding, set in a matrix of quartz and chlorite with abundant oxide of iron (hæmatite) which occurs among the chlorite. The part of the figure marked (1) represents cassiterite, (2) is chlorite and oxide of iron largely interstitial, (3) is quartz. (E. 3,603).

Fig. 3.—South Crofty Mine. The figure shows cassiterite (1), radiate green chlorite (2) which are intimately associated, and quartz (3), also quartz crowded with tourmaline needles (4). (E. 3,604).

Fig. 4.—South Crofty Mine. The figure shows a veinstone consisting of cassiterite and chlorite traversed by a vein of fluorspar. In another part of the slide there is a quartz tourmaline vein. (1) consists of cassiterite with a little chlorite, (2) of chlorite, (3) of fluorspar, and (4) of quartz. (E. 3,605).

Fig. 5.—Wheal Enys. A brecciated veinstone. The fragments

* "On the Veins of Cornwall." *Tr. Geol. Soc.*, vol. ii., 1814, p. 121.

in the slide consist of cassiterite, which in some places, owing to its yellow colour, appears almost black in the photograph, and some quartz. The whole mass is traversed by veins of quartz in which topaz occurs. (1) consists of brecciated cassiterite, (2) quartz frequently crowded with tourmaline needles, particularly where near the cassiterite. Rows of inclusions and of grains of oxide of iron show a zonal arrangement in the quartz. (E. 3,858).

Fig. 6.—Dolcoath Mine, 475-fathom level. The slide shows several periods of disturbance of the brecciated lode. (1) consists of quartz-tourmaline veinstone, and is possibly itself a breccia. (2) infilling consisting of cassiterite, quartz, chlorite, and dusty undetermined inclusions, (3) cassiterite, (4) quartz. (E. 4,278).

CHAPTER XV.

CROSS-COURSES, CROSS-FLUCANS AND SLIDES.

The lodes are intersected by a system of fissures probably produced in Tertiary times. These fissures traverse the district in a direction approximately at right angles to the lodes, from which fact the term "cross-course" is no doubt derived. Although the cross-courses are frequently faults, sometimes sufficiently large to affect mining operations, they have no important effect on the geological structure of the district. Excepting those cases cited in the section dealing with the general distribution of the ores, the cross-courses are unproductive from the miners' point of view. It is impossible to separate them geologically, however, from similar fissures which in some parts of Cornwall have yielded so much iron and silver-lead ore.

In 1778 Pryce defined a cross-course (cross bar, cross gossan, cross lode) to be "either a vein of a metallick nature, a cross gossan, or else a soft earth, clay or flookan like a vein, which unheads and intersects the true lode."*

Elsewhere in the same work "flookan" is defined to be "an earth or clay of a slimy glutinous consistence, in colour, for the most part blue or white, or compounded of both." The same word is now used loosely where the term "cross-flookan" should be employed. According to Pryce, "a cross-flooken runs across through a lode, unheads it and throws it on one side out of its place. There are flookans also which run parallel with metallic lodes and take the name of course-flookans." When clay occurs throughout an ordinary lode it is called a flookan lode. A slide is defined as being "a course-flookan or course-gossan, that either inclines faster or in direct opposition to a metallick lode." There is here no attempt at classification as regards age. Richard Thomas, however, stated that cross-courses and cross-flookans appear to be more recent than lodes or slides, and pass through them without interruption.† He called a cross-course which contains clay a "fluccan." In 1822, Carne distinguished two kinds of cross-courses, the difference between them being both in bearing and underlie. Most of those which have a bearing E. of N. underlie west, and those with bearing W. of N. underlie east.‡ With regard to slides, he states that they traverse every other kind of vein—a statement directly contradicting that of Richard Thomas. The slides, although generally parallel with lodes, may run in any direction. Henwood does not make any statement on the relative ages of the cross-courses and slides, but he remarks that the slides never contain metalliferous minerals, and that they never occur in granite. "Their whole substance consists of soft

* *Min. Cornub.*, p. 319. † Survey, 1819, p. 21.
‡ J. Carne, "On the Veins of Cornwall." *Tr. R.G.S. Corn.*, vol. ii., 1822.

clay, similar in mineral composition to the rocks which they traverse. So close, indeed, is this resemblance, that even the lamination of the slate is often as perfect in them as in the contiguous rock," and "the softness of the slide is frequently the only character distinguishing it from the neighbouring country.'"*

The slides are few in number, seldom exceed a foot in width, and their average underlie is about 45 deg. or 50 deg. Slides are said to occur in Treskerby, Wheal Squire, Wheal Vor, Wheal Friendship, &c. In the districts of Camborne and Redruth the directions of the principal cross-courses and cross-flucans, with their average widths, were tabulated by Henwood, and the results may be presented as follows:—

Bearing.		Number. Camborne.	Redruth.
N. to N 10° W.	...	9	4
N. 10° to 20° W.	...	—	6
N. 20° to 30° W.	...	4	6
N. 30° to 40° W.	...	2	6
N. 40° to 50° W.	...	1	4
N. 50° to 60° W.	...	1	—
N. 60° to 70° W.	...	—	1
W. 20° to 30° S.	...	—	1
W. 50° to 60° S.	...	—	1
W. 60° to 70° S.	...	—	4
W. 70° to 80° S.	...	2	—
W. 80° S. to S.	...	—	2
Average bearing	...	N. 34° W.	W. 35° N.
Average width	...	1·48 feet.	1·62 feet.

Henwood says that the material principally filling the cross-veins consists of quartz and clay, and according as one or other of these constituents predominates they are called cross-courses or cross-flucans, and it is owing to the impervious nature of these flucans that they are sometimes selected as the boundaries between different mines.† The Great cross-course, which can be seen in the adit between Cook's Kitchen and Dolcoath Mines, is a case of an impervious barrier between two mines. The structure of cross-courses is variable, but they have, as pointed out by Mr. Hill, an intimate connection with the "cleaving way" jointing of the granite.‡ They are not characterised by the presence of breccias as a rule; are generally more or less vertical, and are not infrequently faults of considerable magnitude. The larger of them contain quartz with fragments of country rock, while the smaller are mere cracks, that may or may not contain quartz, but along which there has generally been a little faulting. Henwood states that some cross-courses consist of several parallel cracks filled with quartz or other materials. The tabular statements contained in his book have much detailed information concerning the cross-courses in the mines.

Mr. Carne says that there is no connection between the size of cross-courses and the amount of faulting they produce,§ and gives

* p. 282. † Henwood, p. 258.
‡ *Trans. Roy. Geol. Soc. Corn.*, vol. xii., part vii., 1901.
§ "On the Veins of Cornwall," 1822, p. 117.

several examples of considerable faulting by cross-courses which are comparatively narrow, and *vice-versâ*. In Wheal Virgin (Consolidated Mines) a cross-course 2 feet wide heaves the lode 6 fathoms; in Wheal Peevor another of the same width heaves the lode 18 fathoms; at Sparnon a cross-course 8 feet wide heaves the lode only 2 fathoms. In Wheal Unity a flucan 18 inches wide heaves the lode 5 fathoms. In Wheal Squire a flucan 2 feet wide heaves the lode 19 fathoms. A small flucan in Wheal Daniell heaves the lode 14 fathoms, while lodes in the United Mines are heaved only 1 fathom by a flucan over 2 feet wide. The principal cross-courses and cross-flucans of the Camborne and Redruth district are indicated on the map published by Richard Thomas in 1819. The facts relating to a few of the principal cross-courses of this district may be briefly stated as follows:—The Great or County cross-course has been referred to by Berger, Thomas, Carne, and Henwood. Thomas says that it starts from Tolben rock, near Porth Towan, 2½ miles N.E. of Portreath, and goes through to Wheal Jewell. From here southwards it is divided into four branches, each of which is a fault of about 20 fathoms.

Although Berger* states that this cross-course continues its way southwards to Pedn Boar Point, the statement is not proven. Carne remarks that there are two cross-courses seen at some distance from each other in the cliff at Porth Towan, and that they intersect and heave all lodes as far as Wheal Peevor, at which place they run into one another. The eastern one heaves the lodes 54 fathoms and the western one 18 fathoms to the right hand. From Wheal Peevor to Wheal Jewell the heave is 74 fathoms, but further south still, at Wheal Damsel, it runs into confused ground, and heaves the lodes only 16 fathoms.

Henwood appears to disagree with both views, and says that although there are several flucans in Wheal Damsel, Wheal Squire, and Poldory, none of them can be shown to run into the Great cross-course, while the only considerable heave north of Wheal Peevor is in Cliff Down (western part of Wheal Towan), where the heave is to the left hand. Another important cross-course is that which separates Cook's Kitchen from Dolcoath Mine, and is known to dislocate the main lode to the extent of 74 fathoms. Northwards, it passes between North Roskear and East Wheal Crofty, and is the same as that exposed in the cliffs near Samphire Island. At the present time it can be seen in the adit between Dolcoath and Cook's Kitchen, where it is of a clayey or flucany nature, while at Samphire Island it is a quartz vein.

Some cross-courses have, on account of their special interest, received notice from several writers. A north and south cross-course called Skewes flucan, with a slight heave to the left, traverses the mines of Ting Tang, Wheal Damsel, Wheal Jewell, and Wheal Gorland. Between Wheal Jewell and Wheal Damsel it passes through the Great cross-course. A cross-course, designated the Caunter cross-course, separates Wheal Prussia and Wheal Boys, and southwards passes through Wheal Derrick. In Wheal

* *Geol. Trans.*, vol. i., p. 165.

Prussia it is traversed by Butcher's cross-course, and in Wheal Derrick by Wheal Boys' cross-course, both of which are parallel with the County cross-course, the Caunter cross-course bearing about W. 40 deg. N. Tiddy's cross-course contained some ores of copper. It passes from Poldory (United Mines) through Wheal Virgin (Consolidated Mines) and Poldice, where it is called Trussal's cross-course. At the Garras Mine (Gwarnick) there is a silver-lead lode striking approximately north and south. It is 2½ feet wide, and is heaved twice by two slides, each to the extent of about 6 fathoms.*

In the south-western part of the map some remarkable cross-veins have been noticed. Woolf's cross-course, at Great Wheal Vor, consists of quartz. It intersects the old Wheal Vor and the Wheal Metal lodes, and is considered to be the same as that which yielded grey copper ore in the Godolphin Bridge Mine, and lead ore, with oxide of iron, in Wheal Rose.†

* J. Carne, "On the Discovery of Silver in Cornwall." *Tr. R.G.S. Corn.*, vol. i., 1818, p. 120.

† H. Stephens, *Rep. Corn. Poly. Soc.*, 1871, p. 77, "Mineral Phenomena of Wheal Rose." See also R. Hancock, "On the Mineral Deposits of the Old Wheal Vor." *Rep. Roy. Poly. Soc. Corn.*, 1870, p. 101.

CHAPTER XVI.

NATURAL HISTORY OF THE ORES.

I. The Ore Bodies.

The profitable parts of the lodes (containing anything over 1 per cent. of tin) alternate with poor or barren parts. That the ores do not occur uniformly disseminated throughout the lodes is a point which cannot be too strongly emphasised. Generally speaking, the conditions affecting the shape of the ore bodies depended upon (1) the shape of the cavity or brecciated mass in which the ore was deposited, and (2) the nature and jointing (or fissuring) of the country rock in the neighbourhood of the lode. In this district there is no evidence for differentiating the origin of the more remarkably-shaped ore bodies from that assigned to those of ordinary lodes, since all the deposits are connected with fissures.

Impregnated masses formed in the open parts of an irregular fault-fissure, or in a friction breccia of a fissure, together with the metalliferous altered country rock in their vicinity, are known as bunches or pipes. A succession of such bunches makes up a "chute" or "course" of ore. The word "chute" refers to a succession of bunches in more or less vertical arrangement. A "course" refers to a succession of bunches in a more or less horizontal direction. The lodes of the Gwinear district were termed "bunchy" by the miners, but used in that sense the word means that the bunches were uncertain in occurrence. A "pipe" is an elongate bunch within the lode, with its longer axis lying in the direction of underlie of the lode, or "pitching" slightly to one side or the other; or it may be the infilled line of junction of intersecting lodes, or the line of bifurcation of a branching lode. The distinction between the terms "chute," "course," and "bunch" is not very definite, and the use of the terms is a matter of convenience only. "The masses or shoots of ore in any given lode have, generally speaking, a prevailing dip (pitch), and whether they occur in granite or in slate, whether on the eastern or western side of granite tract, this inclination is invariably towards the great body of the slate."*

In Wheal Uny the ore bunches pitch westwards.† The lode is very large, and yielded great quantities of low-grade tin ore.‡

In Wheal Grenville the ore pipes in the lode pitch slightly eastwards. The three chutes of ore in Dolcoath Mine and the chute of ore in Cook's Kitchen Mine, although almost vertical, have a slight easterly pitch in depth. The individual bunches of which these shoots are composed are ill-defined. In Great Wheal Fortune and Great Wheal Vor the shoots incline in the direction of the granite and killas junction, or where associated with elvans they follow the dip of the latter.§

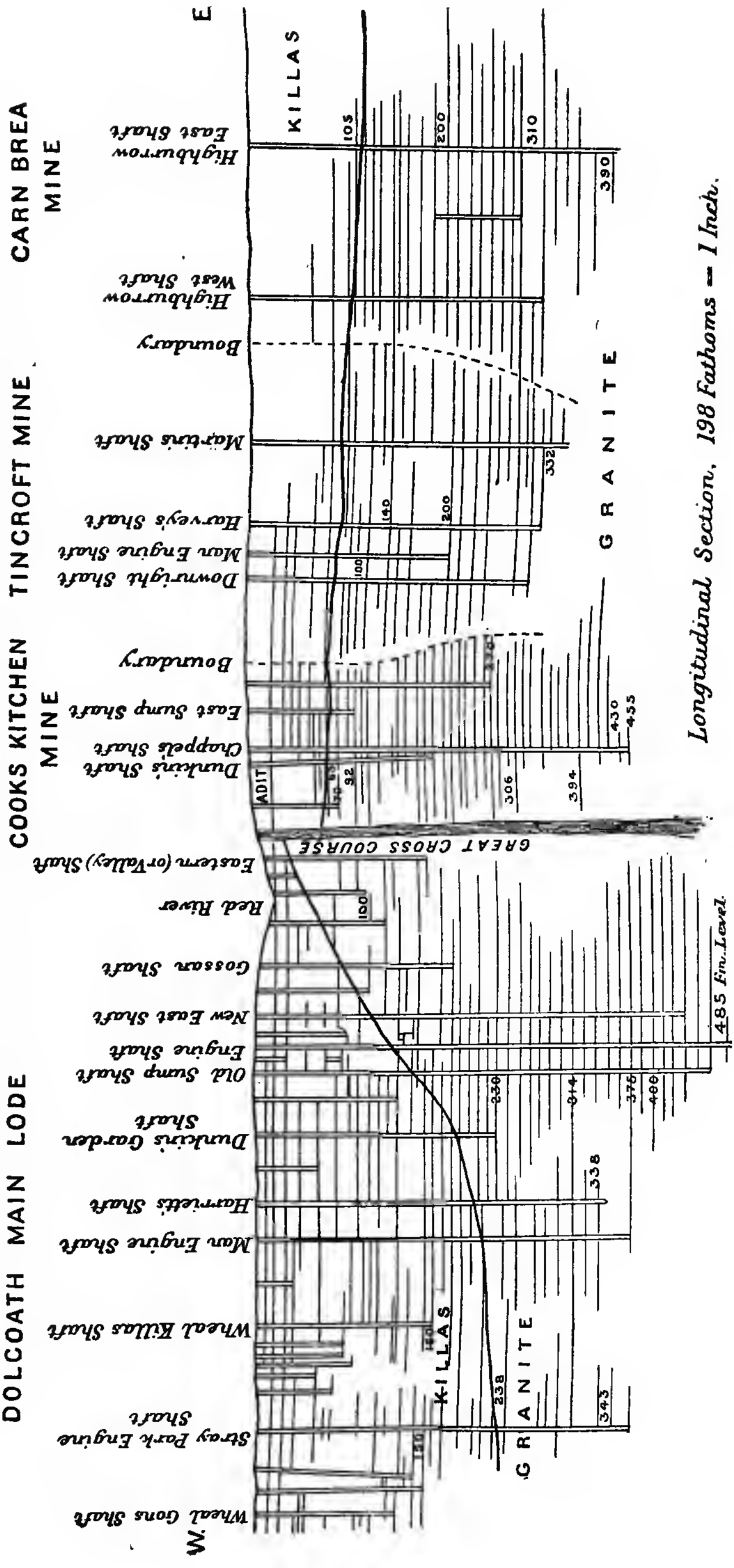
* Henwood, p. 195.

† R. H. Thomas, "Some Observations on the Great Flat Lode in Wheal Uny." *Rep. R. Corn. Poly. Soc.*, 1886.

‡ H. C. Salmon. *Mining and Smelting Magazine*, 1862, p. 318.

§ *Op. cit.*, 1862, vol. ii., p. 14.

Fig. 19.—*Longitudinal Section of the Main Lode of Dolcoath and Carn Brea Mines.*



Longitudinal Section, 198 Fathoms = 1 Inch.

In Dolcoath, the main lode can be divided vertically into three chutes (Fig. 19.) The lode regarded as the main lode strikes from the western boundary of the mine to Harriett's shaft at E. 30 deg. N. Thence to the Old Sump shaft it strikes E. 50 deg. N. (at the 190-fathom level near the junction of the granite and killas). Thence to the Gossan shaft, in the eastern part of the mine, the strike is E. 30 deg. N. The lode then splits into two branches known as the Valley lode and the Valley Caunter lode. The main chute of ore is situated between the Gossan shaft and the Old Sump shaft. This chute is made up of more or less connected bunches which have been worked for copper down to the 190-fathom level, and (after passing through a zone of mixed copper and tin ores) for tin, down to the deepest point of the present workings, which are 490 fathoms below adit, or over 500 fathoms from surface. The width of the bunches varied from a few feet to 60 feet. Thus, the junction of the main lode and South Entral lode is 60 feet wide. From the 150-fathom level to the 200-fathom level the lode varied in width from 7 to 12 feet, and from the 200 to the 300-fathom levels from 1 to 5 feet. At the 338-fathom level the lode was from 6 to 9 feet wide, and at the 485-fathom level the width of the lode, including the altered country rock, is 42 feet in width, carrying 25 lbs. of black tin per ton of stuff.

Another chute of ore occurs in the same lode in the section of ground between Harriett's shaft and Wheal Killas shaft (on the west). This chute is made up of disconnected bunches of ore, showing the same change in mineral contents in depth as that of the chute just described, but has only been explored to the 338-fathom level. In the western part of the mine there is another chute of less importance. The section of ground between Harriett's and Old Sump shaft, striking E. 50 deg. N., is almost barren, and the lode here is wrung up between the first and second chutes above described. The lode was extremely rich in tin ore above, and on the eastern slope of the large "horse" of granite, occurring about the 425-fathom level. (See page 139.) Tin ore also occurs in small strings and veins in parts of the "horse" itself.

In Cook's Kitchen Mine the chute of ore is in the continuation of the same lode as that worked upon in Dolcoath, but is here known as the Highburrow lode. The chute is made up of connected bunches, and has been worked upon from surface to the 430-fathom level. The width of the bunches varied from 6 to 20 feet; at the 400-fathom level the lode is 30 feet wide, and at the 450-fathom level is 66 feet wide. The width of the bunches is always greatest where the lode was branched. Further east an important chute of ore was shared by both Tincroft and Carn Brea Mines. This chute was worked from surface to the 330-fathom level. In the eastern part of Carn Brea Mine the lode is split up into branches.

On the south of the Carn Brea granite is situated the Great Flat lode, which affords some interesting examples of ore bunches. Thus, at Wheal Grenville, the lode underlies 60 deg. S.* (dip 30 deg. S.), and the ore occurs chiefly in pipes separated from each other by intervening portions of poor lode. Observation shows that this lode undulates very gently in the direction of its strike, so that the levels driven along the lode zig-zag slightly from left to right. In West Wheal Frances a chute of tin ore was worked on the same lode. In West Wheal Basset, between Granville's and Pascoe's shaft, there was a chute of tin ore extending to great depth. Part of this chute was known as Pascoe's pipe. Further east in the same mine Thomas's shaft was sunk through a chute. In Wheal Basset some parts of the Great Flat lode are as much as 150 feet wide, but these are at points of intersection of the bunches of the Great Flat lode with other lodes, resulting in the production of a large body of ore of ellipsoidal shape at the junction.†

In Wheal Uny the tin ore occurs in pipes pitching west, the intervening ground being poor.‡

* Foster, p. 640.

† Information from Captain W. James, manager of Wheal Basset.

‡ R. H. Thomas, "Some Observations on the Great Flat Lode in Wheal Uny." *Rep. Roy. Corn. Poly. Soc.*, 1886.

IRREGULAR BUNCHES OR MASSES.—An abnormal development of the lode may form an irregular bunch or mass. In some cases ore bodies occur which bear some resemblance to carbonas. The carbonas of the St. Ives district have, however, given to this term a special meaning. In that region the carbonas are irregular, more or less horizontal "pipes," passing into the country rock along cracks, making a large angle with the lode. Typically, they contain a large amount of schorl. The term "Carbona" as used in the Camborne district does not appear to have received recognition.

In WHEAL BASSET the carbonas are impregnations of the country rock in the vicinity of small fissures which run "counter" to the lodes and so sometimes connect them. These deposits are somewhat irregular and of a soft or "plumb" nature (decomposed granite). As a rule they are uncertain, widening out into a body 6 feet across, or narrowing down to a small string in a short distance. The largest occurred at the 115-fathom level on the west of Carnkie shaft, and contained from 14 to 28 lbs. of black tin per ton of stuff. The veinstone is chloritic and highly ferruginous. The manager of Wheal Basset* considers these bodies to be branches from some of the nine or ten more or less vertical lodes which traverse the mine. Where these branches cross each other the line of intersection contains tin or copper ores, and the pipe-like deposits so formed are more or less horizontal. The carbonas occur mainly in the neighbourhood of Carnkie shaft. The carbonas on the west of the shaft produced mainly copper ores, and those on the east mainly tin ores. Both the lodes and carbonas were richest above the 130-fathom level.

In POLDICE MINE, in Gwennap, a fissure branched off in a south-westerly direction from Singer's tin and copper lode. The body of ore associated with it was known as a carbona.

BALMYNHEER MINE (Wendron).—The deposit consists of a large irregular mass of stanniferous altered granite. A vein or slide about 6 inches in thickness, consisting of white clay and a little quartz and mica, underlies N. 60 deg., and bears E. 32 deg. N. Below the slide the irregular mass of tin-bearing rock varies in thickness from 30 to 50 feet, and underlies in the same direction as the slide. Between this mass and the granite there is no regular plane of separation. Occasionally there is some tin ore above the slide. This mass, which consists of quartz, chlorite, gilbertite, iron pyrites, zincblende, and tin ore, and occasionally a little wolfram, extends for 36 fathoms along the strike of the slide, the lowest workings being at 30 fathoms from surface.† In 1876, 2,200 tons of tin ore were stamped yielding over 1 per cent. of black tin per ton.

HALABEZACK FARM (Wendron).—There is a vein of clay about 2 feet wide which underlies N. 26 deg. A mass of granite about this vein has been worked as an open quarry for the tin ore it contains. The breadth of the deposit is possibly 20 fathoms. In addition to the tin ore there was micaceous iron ore and iron pyrites.‡ The produce varied from 10 to 56 lbs. of black tin per ton of ore.

SOUTH WENDRON MINE.—The deposit here is a very irregular cylindroid of stanniferous rock, merging gradually on all sides into granite, with its axis dipping at 49 deg. from the horizon in a direction N. 25 deg. W. The longer axis of the oval section of the pipe varies from 20 to 60 feet in length, while the shorter is about 10 feet. The mass consists of quartz, mica, gilbertite, a little iron pyrites, and tinstone, and is traversed by a few irregular joints; the stuff is cavernous or honeycombed, and in little cavities there are fine acicular crystals of tourmaline.§

* Captain W. James. † Foster, p. 648.

‡ Charles Fox, "A Deposit of Tin in Wendron," *Miners' Assoc. Corn. and Devon*, 1868, p. 47.

§ Foster, p. 650.

LOVELL MINE.—The South lode is traversed by numerous joints. The principal joints dip and strike with the lode. On one or both sides of the lode there is an altered band of "country" rock, 6 to 12 inches thick, consisting of quartz, mica, gilbertite, chlorite, iron pyrites, copper pyrites, and a little schorl. The lode itself is a dark mixture of quartz, gilbertite, mica, zincblende, chlorite, iron pyrites, and a little copper pyrites, fluorspar, and tinstone. When one of the aforementioned joints diverges from the lode it carries "lodey stuff" with it. The North lode, which is very "bunchy," is 10 to 15 feet wide, and consists of quartz, gilbertite, some iron pyrites, tourmaline, and tinstone.*

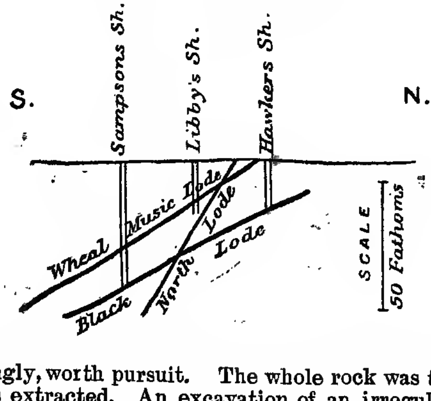
EAST WHEAL LOVELL (Wendron).—The main "chute" of ore in this mine "is in the shape of a long irregular cylindroid or cylinder with an elliptical base generally from 12 to 15 feet long by 7 feet wide." This chute has been followed down from the 40-fathom level to the 110-fathom level as one continuous pipe. There were several other pipes and bunches of similar character. "The East Wheal Lovell pipes and bunches resemble in their mode of occurrence some of the carbonas of St. Ives, but differ in the absence of tourmaline, which is so very abundant at St. Ives."†

PEDN AN DREA.—A curious deposit of tin ore, called a "carbona," occurred in the killas not far from its junction with the granite, at the 68-fathom level. It consisted of a mass of small veins penetrating the killas. These veins branched off from a lode 4 fathoms in thickness. The mass so formed was 25 fathoms long and 11 fathoms wide, the richest portion being in the country rock between the Engine and Martin's lodes.‡

WHEAL VYVIAN.—The deposit has the "character of an enormous granitic lode, bearing 20 to 30 deg. S. of W.," and dipping N. 40 to 55 deg. It is 5 to 10 fathoms wide, or even more in some places, and the composition is similar to that of the country rock. "The whole substance of the lode is thinly interspersed with tin ore, copper pyrites, and also spots of iron pyrites," &c., but these minerals occurred chiefly in small veins and strings running in the same direction as the lode and having a northerly underlie. "The joints of the rock seem to coincide with the veins both in bearing and dip, and where there are crevices in them their faces are commonly coated with fine crystals of tin ore."§

WHEAL MUSIC (St. Agnes).—The lodes which had been worked for many years were at length "split up into minute strings and branches, none of

FIG. 20.—*Wheal Music.*



which were, singly, worth pursuit. The whole rock was then removed and the copper ores extracted. An excavation of an irregular elliptical form of about an acre in area and 25 fathoms in depth" was left.|| (Fig. 20.)

* Foster, p. 649.

† C. Le Neve Foster, "The Tin Deposits of East Wheal Lovell." *Tr. R.G.S. Corn.*, vol. ix., 1876.

‡ M. H. C. Salmon. *Mining and Smelting Magazine*, vol. ii., 1862, p. 143.

§ Henwood, p. 72. || *Op. cit.*, p. 98.

CHACEWATER TIN AND COPPER MINE.—The elvan in this mine is "full of small strings of copper ore which cross the elvan at 45 deg." The ore does not enter the killas at all. There are also small unconnected beds of "red elvan" called "floors" by the miners, which, although quite distinct from the other, are intersected by the copper veins in the same manner.*

CONSOLS MINE (Gwennap).—Near Frances' shaft at the 135-fathom level "for more than 25 fathoms in length and 15 fathoms in height, the lode was from 8 to 12 feet wide, and full of fragments of copper ore, some of the fragments of slate weighing several tons, and occurring, as to the position of their laminæ, in all directions." "Many of these masses and smaller stones had the appearance of having been washed by a flow of water. Above this mixed mass, and in the level above, a great cavity or vug was found many fathoms in length and height, from whence it was conjectured the fragments beneath had fallen."†

WHEAL VOR.—The lode produced ore in killas, but was richer in elvan. The lode was 2 feet wide, but in elvan was 5 feet, and in some places branched into it so as to impregnate the whole elvan and render it profitable for 20 feet in width.‡ "Unconnected" masses of tin ore occurred in the elvan as small veins and irregular bodies.§

At the 180-fathom level, the lode from being 2 feet wide suddenly broadened to 6 feet, and consisted of chloritic products and tin ore, either separately segregated or more or less "mixed." Wood tin ore occurred in scattered grains, in small isolated masses, or in very fine veins, often no thicker than paper, but always with the fibrous structure.‖

At EAST POOL MINE there was a somewhat remarkable occurrence at the junction of the granite and killas, a position highly favourable for the production of irregular deposits. The Engine lode underlies south 13 deg. to 27 deg., and strikes the granite at about the 135-fathom level. At this place there is a ridge in the granite some 35 fathoms in height, which trends in much the same direction as the lode (see page 117). The Engine lode coming down from surface follows down the southern flank of this ridge and enters the granite near the foot. On the other flank (northern side of the ridge) the Great Wolfram lode, over 12 feet in width, underlying north, emerges from the granite in its upward course and following the junction of the granite and killas on the northern flank of the ridge bends over it at its apex, and finally joins the Engine lode. The ore in the Wolfram lode, near the junction of the granite and killas, consisted of mundic, copper, tin, and wolfram.¶ A solid branch of wolfram ore 4 feet in width was found in the lode below the 140-fathom level.

FLOORS.—In the Camborne district the term "Floor" is applied to a more or less horizontal roughly-sheeted deposit, branching off from the lode into the country rock. Thus, a deposit in a "bedding plane" or horizontal crack in the granite would be regarded as a floor. The term is loosely applied and refers to the general shape of the body, but it is not used for stockwork deposits.

Phillips regards "Floors" or "Carbonas" as stockwork deposits.**

The "tin floors," in the parish of Madron, were made up of small fissures or veins containing tin ore, which follow the inclination of the strata and appear to be branches from a central body.††

* J. Carne, "On Elvan Courses." *Tr. R.G.S.*, vol. i., 1818, p. 104.

† De la Beche, p. 324.

‡ J. Carne, "On Elvan Courses." *Tr. R.G.S. Corn.*, vol. i., 1818, p. 238.

§ Henwood, p. 238.

‖ W. Argall, "On the Occurrence of Wood Tin." *Journ. Roy. Inst. Corn.*, vol. iv., 1873, p. 255

¶ H. C. Salmon. *Mining and Smelting Magazine*, 1862, p. 385.

** J. A. Phillips and H. Louis, "A Treatise on Ore Deposits," 1896, p. 169.

†† John Hawkins, "On Tin Floors, &c." *Tr. R.G.S. Corn.*, vol. ii., 1822, p. 36.

In Wheal Vor floors containing tin ore, and of a composition similar to that of the lode, branched off from the lode nearly horizontally into the killas.* In South Crofty Mine the main lode in the killas, near the junction of the granite and killas, branched off into floors. The killas was greatly disturbed and mineralised. At the 50-fathom level in West Roskear Mine, the divisional planes of the adjacent slates were infilled with copper pyrites and mundic, thus forming floor deposits as branches from the main lode.

II. Genesis of the Ores.

The limited number of types of ore deposit in the region under consideration enables the discussion of their genesis to be confined to a mode of origin the explanation of which was first suggested by Elie de Beaumont† and Daubrée.‡

Daubrée's results were based largely on experimental researches carried out by him in 1849, although the principle was first suggested by him in 1841.§

In reference to the tin lodes of Cornwall, the works of the late Sir Clement le Neve Foster stand pre-eminent for the examples brought forward by him, which have become classic, as illustrating the connection of the tin deposits with lines of greisen action; a fact entirely supported by Mr. J. H. Collins, author of many well-known works relating to the geology of Cornwall.

Although the tin and copper deposits are without doubt connected with the granite, yet since they occur in fissures, generally about the peripheral portions of the granite masses, they should not be regarded as being immediately connected with the country rock in which they are enclosed. The ores are now supposed to have originated by "extraction" of metalliferous solutions emanated during the final phase of consolidation of the acid magma from which the granite was formed. The secretion of the ores depends upon the principle known as "magmatic extraction," by which is meant the extraction in solution of metalliferous minerals from a still completely fluid or partially consolidated magma, by means of other materials which combined with them, and may be termed "carriers." The precise chemical and physical phenomena are still only vaguely known, but the explanations offered by Professor Vogt, of Kristiania, form a landmark in the field of ore deposits of the kind here considered, and the conclusions arrived at by him are the most satisfactory hitherto formed.|| Professor Vogt has clearly stated his views in an ingenious argument, in which is shown how tin veins in granite may be compared with rutile-apatite veins in gabbro.**

* Henwood, Table xlv

† "Note sur les Emanations Volcanique et Metallifères." *Bull. de la Soc. Geol. de France*, 2e Serie, Tome iv., 1846, p. 1255.

‡ "Etude Synthetique de Geologie Experimentale," 1879, p. 29

§ "Memoire sur le Gisement, la Constitution et l'Origine des Amas de Minerai d'étain. *Ann. des Mines*, 3e Serie, Tome xx., 1841, p. 65.

|| J. H. L. Vogt, *Zeit. f. Prakt. Geol.*, 1894-95-98-99. See also Professor Kemp's paper, "The Rôle of the Igneous Rocks in the Formation of Veins," *Tr. Am. Inst. Min. Eng.*, 1901, which is a recent valuable contribution to the science.

** *Op. cit.*, 1895, pp. 447, 474.

In both cases the extraction process is mainly dependent on the nature of the compounds formed with halogens present in the magma. Both magmas contain phosphoric acid, which forms compounds readily soluble in acids, but it is present in larger quantity in gabbro than in granite. The metals forming compounds with the halogens (fluorine and chlorine) are able to pass into fissures along with phosphoric and hydrofluosilicic acid. The former is characteristic of gabbro, but only accessory in the case of granite. Hence rutile with phosphates, possibly a little silica and some alkaline earths, are concentrated in fissures mainly through the agency of chlorine in the case of gabbro. In granite, cassiterite, wolfram and silica, together with a little phosphate and also lithia and potash, are extracted by fluorine. Each rock has its characteristic extraction products; and possibly they existed as dissolved gases, which on relief of pressure at any point, as by a fissure in the consolidated crust, were permitted to vapourise and escape. It is this assumption that gases and not liquids formed the main part of the emanations that prompted the use of the terms "pneumatolytic" and "fumarole." This implies that gas was the principal agent in the secretion of tin ores at least. The only difference in the meaning of these words is that "pneumatolysis" refers to the action of gases above critical temperature (and hence generally of deep-seated origin in connection with bulky igneous intrusions), while "fumarole" refers to gases considerably below their critical temperature.

The whole history of the actions which finally resulted in the deposition of the metalliferous minerals of the cassiterite veins is very complex, but the elements which took part in these operations are discovered in the secondary minerals, which commonly occur in the altered country rock, in the vicinity of the fissures which form parts of the lodes. The minerals of the "tin-copper" lodes of Cornwall can be broadly divided into two classes, corresponding with the minerals of the infilled fissures and those of the altered country rock. To the former class belong such minerals as cassiterite, wolfram, scheelite, mispickel, copper pyrites (and other sulphides), mundic, arsenical pyrites, and other metalliferous minerals, together with quartz, apatite, schorl, chlorite, fluorspar (occasionally in great quantity), &c. These have been introduced into the lodes by gases or solutions traversing them. To the second class belong tourmaline, axinite, topaz, garnet, and various secondary micas, chlorite, &c. These minerals have been formed by the action of vapours on the country rock, *e.g.*, tourmaline in granite, and axinite in lime-bearing rock by addition of boric acid; garnet veins in greenstone by addition of silica during metamorphism by granite. To these may also be added iron pyrites, which results in many cases from alteration of oxide of iron in the country rock by sulphur vapours.

As a whole, then, the materials brought up in solution were composed of the elements—tin, wolfram, arsenic, copper, iron, &c., silicon, chlorine, fluorine, boron, phosphorus, oxygen sulphur, hydrogen, and carbon, together with lead, silver, zinc, nickel, cobalt, manganese, &c., which, as Vogt points out, may or

may not be present but often are, in small quantities, characteristic of cassiterite veins.

The early history of the metalliferous minerals is intimately bound up with the more general petrological problems concerning rock magmas. In all probability the metallic elements were diffused uniformly throughout the magma when it was intruded. As the mass cooled the basic materials of the magma crystallised out first, while the more siliceous material (which resulted from their withdrawal), as crystallisation proceeded, drove out the active gases, gradually concentrating them in a siliceous "residual magma."

It is in the latter that the gases and the metals extracted by them are concentrated, but "so long as they remain in the magma, they must be regarded as belonging to it and playing their part along with the other constituents in producing the final result."* Fluorine, chlorine, boron, phosphorus, and steam are common characteristic constituents of granite magmas, and assist in keeping some of the free silica fluid to a late stage in the history of the consolidation, and possibly even decompose the first formed minerals, with, for instance, the production of tourmaline from ferro-magnesian minerals, &c. In this manner they are concentrated in the fluid part of the consolidating mass and carry with them tin, wolfram, and other metals, and in fact it is possible that the extraction of these compounds does not take place until the magma is actually consolidating.

The silica or silicic acid combined with fluorine is carried up into the veins as SiF_4 (silicon fluoride), or hydrofluosilicic acid, from which quartz is derived by decomposition in contact with water. Fluorine, and possibly also chlorine in the same way extract lithium, potash, &c., which go to form secondary mica. Most of the other bases are also attacked in the same way by fluorine, with which in all cases steam co-operates powerfully. The reaction in the case of tin may be represented by the equation—

$$SnF_4 + 2H_2O = SnO_2 + 4\,HF.$$

The fluoride of silicon may be supposed to be decomposed in the same way.

In the case of the iron and titanium of basic rocks, each reaction is represented by a similar equation in which, instead of fluorine, chlorine is the carrier.

While tin is a characteristic accessory of granite, it has been pointed out long since that copper frequently occurs in cassiterite veins, and in Cornwall the association of stanniferous and cupriferous minerals is so striking that the term "tin-copper" veins applied to the lodes is quite appropriate. They are cassiterite veins characterised by the presence of copper sulphide and tourmaline.†

* J. J. H. Teall, "The Evolution of Petrological Ideas." *Q.J.G.S.*, 1901, vol. lvii., p. 76.

† J. H. L. Vogt, "Zur Classification der Erzvorkommen." *Zeit. f. Prakt. Geol.* 1895, p. 152.

The general relations of the deposits of copper to those of tin have already been pointed out. It will be seen that both are associated with minerals derived from the granite. Dalmer has shown that in the Erzgebirge, the sulphide zinc and lead deposits are, in common with the tin lodes, connected with the consolidation of the granite, but while the tin ores were deposited in or near the granite, the zinc and lead ores were only deposited at a distance from the granite.*

A similar peculiarity is noticeable in the relations of the tin and copper deposits of this region. Dalmer, in reference to the Altenberg, supposes that the tin ores were extracted and deposited while the interior of the magma was still fluid; and with regard to the position of the deposits in reference to the granite he states that the zone-like arrangement cannot be regarded as accidental. It seems probable that part at least of the sulpho-compounds in the lodes were extracted at the same time as the tin, but whether through the action of fluorine or not is uncertain. In addition to the mineralisers already mentioned, there are boric acid, sulphuretted hydrogen, carbon dioxide, &c. The part which the boron plays in the extraction of the metals is at present unknown. The simplest explanation is that sulphuretted hydrogen helped largely in the actual secretion of copper and other sulphide ores; but it is not improbable that fluorine, and even boron, had something to do with their extraction from the magma. In acid magmas sulphur is not generally present in such quantities as in basic magmas. In the later stages of the consolidation of the acid magma the sulphur compounds are driven out and play their part in the secretion of copper and other metals.

The reactions connected with the extraction of cassiterite and wolfram took place at high temperature and pressure. Those connected with the extraction of copper and the other sulphides took place under the same conditions, but the ores continued to be deposited in the lodes after the deposition of tin and wolfram had practically ceased. The connection of the lead and silver ores with those of tin and copper is obscure; but from their general distribution and relations to the tin and copper deposits it seems probable that some, at least, were derived from the granite in a manner similar to, but at a later date than, the copper ores. Unlike copper and tin, the ores of lead and silver have not been found in lodes in granite, but, on the other hand, the greatest lead lodes in Cornwall occur in the killas, and have a strike similar to that of the cross-courses of the district in which they occur. The minerals so characteristic of the "tin-copper" lodes are generally wanting in the "lead-silver" lodes, except in those cases where the lead and silver occur in the ordinary cassiterite lodes. In the latter the lead and silver is generally accompanied by zinc, copper, and cobalt ores, iron pyrites, or mispickel, and carbonates. In two instances in the Camborne district lead occurs in cross-

* K. Dalmer, "Der Altenberg-Graupener Zinnerz lagerstätten District," *Zeit. f. Prakt. Geol.*, 1894, p. 321.

courses. In one case it is associated with silver, and in the other with copper and antimony. The facts point to the conclusion that the ores of lead and silver arrived at a late period in the history of the lodes, but not so late as in some cases to preclude their extraction in the later stages of the actions connected with the deposition of tin and copper ores. Their deposition continued to take place for some time after the processes connected with the extraction of tin ore and the bulk of the copper ore had ceased.

The chemico-physical aspect has been worked out by Svante Arrhenius,* who shows how metals such as tin, copper, lead, zinc, and iron can exist together as sulpho-salts in an aqueous extract, while their behaviour is mutually independent of one another. In the aqueous extract are also sulphuretted hydrogen, hydrochloric, hydrofluoric, boric and carbonic acids, and silica. Hence it appears that at high temperatures the liberation of the active compounds of tin and tungsten, &c., with fluoric and silicic acids and copper, &c., takes place; and it is only at low temperatures that the more soluble, less active lead, zinc, &c. compounds are liberated, so that their deposition as sulphides does not occur until a late stage. It is also possible that some of the materials were even brought up as solid particles, mechanically suspended in water.

III. Distribution of the Ores.

The general distribution of the lodes has already been described. In this section the general distribution of the ores, together with a more detailed statement of their vertical arrangement in the lode, will be considered. Between Camborne and Truro the lodes and elvans have a similar geological occurrence and geographical range. With respect to the granite, the richest mines are those situated along the granite margins and in the altered killas beyond. It has already been seen, however, that the granite had consolidated to a considerable depth, and, indeed, the elvans were intruded before mineralisation of the lode fissures began. The peripheral portions of the granite itself, therefore, were very favourably situated for the formation of important ore bodies in it. Speaking generally, the more important tin deposits of this district have occurred within the granite margin, and not infrequently in the altered killas beyond, particularly where the lodes are parallel to the granite margin. In some instances the chutes of tin extend to considerable depths in the granite, as for example in Dolcoath Mine, where but little tin ore of value was encountered until the granite was struck; but after this, for 300 fathoms within the granite (down to the 490-fathom level), the lode has yielded enormous quantities of tin ore. At the bottom of the mine the lode is 42 feet in width, and contains 25 lbs. of black tin per ton of stuff (1·008 per cent.). On the other hand, there are many deposits of tin occurring in close proximity to granite but which

* "Zur Physik des Vulkanismus." *Geol. Föreningens*, 1900, p. 415.

are not actually in that rock. That is to say, the lode, although passing from the killas into the granite, was only worth working in the part enclosed by the killas. In the parish of Breage, for instance, there are two mines situated near one another which show remarkable and instructive differences. The lodes of Wheal Vor were of enormous value while in the killas, but in granite were utterly worthless. Great Work Mine, not far distant from Wheal Vor, appears to have been very rich in granite but poor in the killas. The great ore chutes of both mines plunge away eastwards approximately parallel to the subterranean surface of the granite.*

Similarly, the principal courses of tin ore in Pedn an Drea Mine plunged westwards with the granite margin. At the St. Day United Mines the ores occurred principally in the killas, but near the granite, which here plunges eastwards. The ores of copper and tin occurred in a course of ore extending in the direction of strike of the lode for over 700 fathoms, from surface to the 130-fathom level. Below this, and roughly parallel to it, was a course of tin ore which was worked to a depth of 205 fathoms below adit.

In West Poldice and Unity Wood Mines, a course of tin and copper ores extends from the granite margin into the killas for about 300 fathoms to a depth of 125 fathoms below adit. Similar instances are not lacking from other districts, as for instance at St. Just, where the richest mines are situated round the granite margin. This apparent selection of horizon is brought out forcibly when the case is viewed on a larger scale. Thus, instead of taking a single great ore chute, a succession of them may be selected in any single series of lodes traversing the district. For example, the series of lodes upon which are situated Camborne Vean, Dolcoath, Cook's Kitchen, Tincroft, and Carn Brea Mines, have been of enormous value for a length of two miles. Some of these mines are already exhausted in depth, and under any circumstances it would be improbable that these lodes should be as rich for a depth of two miles as they have been for a length of two miles in the direction of strike. There appears to be an explanation for this. The continuation of some of the larger lodes in depth is a matter of certainty, but that they will prove as rich at great depths within the granite is another question. Supposing that at the time the lode was being formed the solutions containing tin were rising through the fissure. A little tin ore was deposited regularly in the fissure at points from the greatest depths reached by the fissure to the higher levels. At any particular place, however, say the margin of the granite, the conditions might have been such that the whole of the tin still remaining in solution arriving there was deposited. In fact, it is unlikely that the tin could be carried in solution much further, owing to the low temperature at the margin of the granite. This explanation does not suggest that it is impossible for the tin ore to be deposited at great depths, and all it points out is that at certain

* Henwood, p. 54.

horizons, such for instance as the granite margin, the ore bodies of greatest commercial value are likely to be formed. With different conditions, such as a greater depth of cooling of the granite before the arrival of tin, the horizon at which the great ore bodies will be formed will also be different.

There appears to be some analogy to the tin deposits of the Altenberg (Erzgebirge). In these deposits the tin ore began to be deposited shortly after the intrusion of the granite; the peripheral portions of the granite were scarcely consolidated before fissuring commenced. The tin deposits were formed mainly in the overlying rocks or in the portions of the granite which were the first to solidify and crack. As the crust grew thicker, fissuring in the deeper portions took place less easily, and was not so readily accessible by "tin-bearing superheated gases of the magma."*

With regard to the copper ores it appears that similar observations might apply, with this exception, that the copper ore was arriving after the arrival of tin ore had ceased; and, again, copper ores are liable to reconcentration by being dissolved and redeposited. Copper ore as a rule has been more abundant in the parts of the lodes in killas than in granite. Thus there are the upper portions of the lodes in Dolcoath, Cook's Kitchen, &c.; South Crofty, South Roskear, East Pool, &c.; the United Mines, Consolidated Mines, and other places in Gwennap, and the lodes in Wheal Basset. In all these mines the copper ore occurred in great quantities in the killas, but in granite were much poorer. There is an important exception in the once magnificent ore chute at Tresavean Mine. Tresavean Mine is situated on the margin of the granite. The lode has an east and west strike, and is nearly vertical. The copper ores occurred from surface in an immense chute within, but parallel to, the subterranean surface of the granite, which here plunges eastwards below the slates. This chute, in the part of the lode in granite from surface to the 310-fathom level, was of great value, but in the killas the lode was not worth working. Trethellan Mine, situated entirely in the granite on the west of Tresavean Mine, worked the upper part of this chute. Treviskey Mine, situated in killas on the east of Tresavean Mine, did not strike the chute except at great depths.

Certain areas, on account of the ores for which they were particularly celebrated, have come to be regarded as tin districts or copper districts. Thus Gwennap is regarded as a copper district; Wendron and Porkellis as tin districts; Camborne and Redruth as tin and copper districts. Broadly speaking, the districts situated entirely in the granite have produced mainly tin ore; those entirely in killas mainly copper ore; and the marginal areas have, as far as this district is concerned, yielded both tin and copper ores.

In describing the general distribution of the ores it is convenient to speak of them in their relation to the granite masses. The less common ores will be treated of elsewhere. (See Fig. 1.)

* Karl Dalmer, "Altenberg-Graupener Zinnerz Lagerstätten," *Zeit. f. Prakt. Geol.*, 1894, p. 317.

Carn Brea Granite Region.—The richest ore deposits of the whole district under consideration, and indeed of the whole of Cornwall, occur on the northern margin of the Carn Brea granite. The lodes near the granite boundary enter the granite in depth, and from yielding large quantities of copper in the upper levels became exceedingly rich in tin ore in the underlying granite. The deposits in the lodes to the north have similar characteristics, but the granite was struck at greater depths in these mines, which are now yielding considerable quantities of tin ore. Further north still, the deposits contained but little tin, while they have yielded considerably less copper than those nearer the granite, and they have not been explored to the same extent. Along the southern margin of the Carn Brea granite, and in the strip of country represented by the killas occurring between the Carn Brea and Carnmenellis granite masses, the district has been of enormous value, and, like the district on the northern margin of the granite, continues to yield tin ore. These deposits occur in lodes outcropping in the killas situated in a shallow trough-shaped hollow in the granite which deepens as it goes eastwards to Wheal Basset. Copper occurred in the upper parts of the lodes, but was particularly plentiful in Wheal Basset and the neighbouring mines.

Carn Marth Granite Region.—The Carn Marth granite is situated in the heart of the great mining area. In the middle of this mass the mines worked chiefly for copper, but not to great depths. Lodes containing tin also occur. In the killas on the north of the Carn Marth granite there is an important mining district now idle which yielded both tin and copper ores. The lodes in which the deposits occur may be regarded as the eastward continuation of the lodes on the north of the Carn Brea granite. This great mineral belt is over a mile across, and from Gilbert's Coombe to Wheal Daniell its length is over 3 miles. On the western margin of the Carn Marth granite the most important mine was Pedn an Drea (near Redruth Station), which yielded both tin and copper ores. On the eastern margin the mines contained both tin and copper ores, but they were particularly noted for their wealth of copper. The districts eastwards are those of St. Day and Gwennap. The St. Day district yielded both tin and copper ores. The Gwennap district, situated in killas, is famous for the copper ores it has yielded. Eastwards from Gwennap towards Baldhu and Newbridge the mines have yielded both tin and copper ores, but tin was proportionately more abundant than copper.

Carnmenellis Granite Region.—No deposits of importance occur on the eastern margin of the Carnmenellis granite. On the northern margin Tresavean Mine has yielded great quantities of copper ore and but little tin. From Tresavean Mine, westwards, along the margin of the granite as far as Wheal Buller and Basset, the mines produced both tin and copper ores. Westwards, between the Carn Brea and Carnmenellis granites, is the important mining district referred to under Carn Brea. On the western margin of the granite there are some important mines near Crowan and on the south. Crenver and Wheal Abraham, which is a mine situated

in the killas west of Crowan Church town, yielded tin and copper ores, but chiefly the latter. On the south of Crowan Church town there are some tin mines from Polcrebo Downs to Prospidnick, situated along the granite margin. Finally, from the margin of the granite near Wendron into the interior of the granite mass, there is quite an extensive tin mining area, in which tin ores with occasionally other minerals such as copper, zinc, &c., occur on the east of Coverack Bridge, near Laity, Porkellis Moor, Garlidna, and Halabezack.

In the south-east corner of the map there is part of the mining district of the parish of Breage. In this district Wheal Vor and other important mines yielded tin ore to great depths and but little copper.

The group of mines on the north of this district, near Porth Towan, have yielded mainly copper ores, and belong to the mineral district extending northwards towards St. Agnes Head and Cligger Head, which at St. Agnes has yielded such immense quantities of tin ore.

DOLCOATH AND COOK'S KITCHEN DISTRICT.—The following account is a more detailed description of the geological position of the ores in the lodes in a few selected cases :—

In the Dolcoath and Cook's Kitchen series of lodes, situated near the northern margin of the Carn Brea granite, the granite is encountered below the slate at various depths in the different mines. At Stray Park (the western end of Dolcoath Mine) the granite was encountered in sinking on the main lode at about 250 fathoms from surface. Eastwards, from Stray Park shaft to Dunkin's shaft, the granite rises to from 250 fathoms to 215 fathoms from surface, and at the eastern end of the Dolcoath sett is roughly about 30 fathoms from surface. In Cook's Kitchen Mine the granite was struck at about 90 fathoms from surface ; in Tincroft Mine at about the 105 ; and in Carn Brea at about 135 fathoms from surface.* At the western end of Dolcoath Mine (in Stray Park), copper ores occurred in the lode from surface to about 230 fathoms below surface, or to within 20 fathoms of the granite. At Dunkin's shaft (Dolcoath) copper ores occurred in the lodes from near the surface to about 215 fathoms below surface; that is to say, the lodes yielded copper from surface to the junction of the killas and granite. At the eastern end of the same mine, copper ore occurred to about the same depth, but here the copper is at a depth of 185 fathoms within the granite. In depth copper ore is entirely absent. In Cook's Kitchen Mine the copper ore occurred from surface to 185 fathoms below surface, or 95 fathoms in the granite, but it continued to occur in less quantity to a depth of 345 fathoms below surface, or 245 fathoms below the junction of the granite and killas. In Tincroft Mine copper ores occurred to a depth of 175 fathoms from surface, or 70 fathoms in the granite. In Carn Brea Mine the copper ores occurred from near surface to a depth of 160 fathoms, or 25 fathoms in the granite, but some lodes yielded copper ores to a depth of 224 fathoms below surface, or 90 fathoms below the granite and killas junction. In Wheal Druid there was not much copper below a depth of 95 fathoms from surface, but it continued to occur in small quantities to 140 fathoms from surface.

The position of the tin ore in this series of mines is as follows :—

In Stray Park (Dolcoath) tin ore commenced to occur in quantity at a depth of 224 fathoms from surface, and the lode continued to yield tin ore to a depth of 380 fathoms ; thus the lode yielded tin ore from 25 fathoms above the granite surface to 130 fathoms below. In the eastern part of Dolcoath Mine the great ore chute commenced to yield tin ore at a depth of 170 fathoms below surface, and has continued to yield tin to a depth of about 510 fathoms below surface, or about 320 fathoms in the granite. At

* These figures are approximate only.

this depth the lode is of wide low-grade stuff containing very fine-grained tin ore.

In Cook's Kitchen Mine the distribution of the ores was more irregular, but the greatest amount of tin ore commenced to make its appearance in the lode at a depth of about 200 fathoms below surface, and the lode continued to yield tin ore to a depth of 455 fathoms from surface, or from 110 fathoms below the junction of the granite and killas to 365 fathoms below. In Tincroft and Carn Brea Mines the tin ore occurred from surface, where it was worked in olden times,* to a depth of 415 fathoms below surface, or from about 120 fathoms above the granite to about 280 fathoms within the granite. Tin ore did not occur in great quantity above a depth of 80 fathoms below surface.

Generalising the facts concerning this range of mines it will be seen that the copper ores occur in abundance from near the surface to depths varying from 160 to 345 fathoms below surface; or, stating this in another way, they occur from surface down to the granite, and passing into the granite may continue to occur for distances of from 25 to 170 or even to 245 fathoms below the junction of the granite and killas. Tin ore, on the other hand, did not generally occur in abundance near the surface, and as a rule the lodes did not yield much tin ore until they were worked in granite. After striking the granite the tin ore occurred in the lodes to the deepest points attained in mining.

In sinking through the lodes copper ores are first encountered; then comes a very ill-defined, discontinuous zone in which both tin and copper ores may be profitable, and, finally, in depth, only tin ore occurs.

Mispickel or arsenical pyrites occurred chiefly in the upper workings, but is not absent from the lode in depth.

The silver ores of Dolcoath were all raised from the Silver lode above a depth of 100 fathoms. In this lode arseniate of cobalt and copper ores also occurred.† Some of the Dolcoath tin ore contains cobalt in quantities up to ·5 per cent.‡ Pitchblende and bismuth occur in the same mine.§ Wolfram and pitchblende occur in one of the lodes of Tincroft Mine.||

DISTRICT NORTH OF DOLCOATH AND COOK'S KITCHEN.—The series of lodes situated on the north of the Dolcoath—Cook's Kitchen series, may be dealt with in a similar manner.

This group of lodes has been worked by the following mines:—North and South Roskear, Wheal Knight and North Crofty, South Crofty (including the old Longclose Mine, Dudnance and Penhellick), East Pool, Wheal Agar, and Wheal Tehidy. The granite was never struck in depth in North or South Roskear or in Wheal Tehidy.

In South Crofty the granite was first met with at a depth of about 140 fathoms, but westwards it was not encountered. In East Pool the granite was met with at a depth of from 135 to 150 fathoms from surface. In Wheal Agar it is a little nearer the surface, while in Wheal Tehidy it may be about 120 fathoms below surface.

In North and South Roskear Mines the copper ores appear to have been particularly abundant from the upper levels down to about 180 fathoms from surface, but they continued to occur to 285 fathoms from the surface.

* Henwood, p. 205. † Carne, p. 105.

‡ R. Pearce, "Note on the Occurrence of Cobalt in connection with Tin Ore." *Journ. Roy. Inst. Corn.*, vol. iv., 1872.

§ R. Pearce, "Note on Pitchblende." *Tr. R.G.S. Corn.*, vol. ix., 1864.

|| Carne, p. 104.

Zincblende and galena occurred in some quantity in the upper levels. Arsenical pyrites was abundant in South Roskear between the depths of 100 and 132 fathoms below surface.

Tin ore occurred in the upper parts of the lodes at the western end of these setts (particularly in North Roskear) associated with lead, zinc, and copper ores. It was first met with in any quantity at depths from 100 to 150 fathoms below surface, and was of some value to the bottom of the mine. In Wheal Crofty (Wheal Knight) the lodes contained copper, zinc, and lead ores above a depth of 100 fathoms from surface.

In the two mines North and East Wheal Crofty (part of South Crofty) the copper ores appear to have ceased to be of great value below a depth of 130 fathoms from surface, but they continued to occur in smaller quantity to greater depths, where they were accompanied by tin ore. In East Crofty (part of South Crofty) zinc occurred in Reeves' lode at a depth of 140 fathoms from surface. In South Crofty copper ores and mispickel occurred in quantity from near the surface down to 140 or 150 fathoms from surface, or from surface down to the killas and granite junction, and a little way in the granite. Copper ores are not of much value below this. Zinc occurred in this mine below adit level. Tin ore was first met with in quantity at about 80 fathoms from surface, or 60 fathoms above the granite and killas junction; but it continues to occur down to the deep levels, well within the granite.

In East Pool Mine copper ores occurred in quantity in the lodes from near the surface to about 166 fathoms below surface, or to about 30 fathoms in the granite. Tin ore appears to have been of value from a depth of about 90 fathoms from surface to the bottom of the mine, but in Wheal Agar, at least, the outcrops of the lodes were worked by the old miners presumably for tin ore. Wolfram occurred in quantity from a depth of 146 to 196 fathoms from surface, or from about the junction of the granite and killas to about 40 to 55 fathoms in the granite, and continued to occur down to near the 300-fathom level in quantities sufficient to warrant the erection of a magnetic separator able to treat 10 tons of concentrates a day for the separation of wolfram and tin ores. Silver, nickel, cobalt, and arsenic also occur in this mine. In Wheal Tehidy, tin, copper, and zinc ores occur.

Generalising these facts, it may be said that in this series of lodes the upper parts were copper bearing, and where granite was encountered the lodes continued to yield copper ores for some distance in it. In depth the lodes are tin bearing. Wolfram occurs in large crystalline masses with quartz and arsenical pyrites, principally in the granite near the junction of the granite and killas.

DISTRICT OCCUPIED BY THE "GREAT FLAT" LODE.—The Great Flat lode and the nearly vertical lodes which intersect it form an important series extending from South Condurrow to Wheal Uny.

The Great Flat lode crops out along the southern margin of the Carn Brea granite. Between South Condurrow Mine and West Wheal Basset it is practically wholly enclosed in granite, but on the east of the latter it strikes out of the granite, and for the rest of its course eastwards through Wheal Uny it lies near and parallel to the junction of the granite and killas. The Great Flat lode has been principally wrought for tin ore from surface to a depth of over 300 fathoms in the granite. The other (more or less vertical) lodes which intersect and heave the Great Flat contain principally copper ores, but tin ore is also present in them, as for instance in the case of the Middle lode at South Condurrow Mine, where tin ore occurred in payable quantity near adit level, which is 50 fathoms above the line of intersection of the Middle and Great Flat lodes. The lodes in South Wheal Frances also contained tin ore in the upper levels. Several of the lodes in West Wheal Basset also produced both tin and copper ores.*

* J. Maynard, "Remarks on Two Cross Sections." *Rep. Corn. Poly. Soc.*, 1871, p. 202.

Copper ores occurred in all the lodes of this series. At South Condurrow there is a little copper ore and native copper in the upper levels of the Great Flat lode. In going eastwards all the lodes became richer in copper ores. At South Carn Brea Mine and Wheal Uny copper ores occurred in the upper part of the Great Flat lode.* In Wheal Uny it continued to occur with tin ores to a depth of over 220 fathoms from surface. Only recently in Wheal Basset about 10 tons of grey copper ore have been broken from the Great Flat lode at a depth of over 250 fathoms from surface, and in this mine it is no uncommon thing to find copper ores at this depth in small quantities. The other lodes in Wheal Basset yielded immense quantities of copper ores to a depth of 150 fathoms from surface, but below this were poor.

Throughout this range of mines the upper part of the Great Flat lode contained copper ores, but to greater depths and in much larger quantity eastwards, where it is near the junction of the granite and killas, than on the west, where it is almost wholly in granite. This lode contains mainly tin ores. The other lodes contain chiefly copper ores, and in these they were particularly rich in the neighbourhood of Wheal Basset.

GWENNAP DISTRICT.—In the Gwennap district an important group of lodes extends from the United Mines to Wheal Jane. In none of its mines has granite been encountered in depth. From the United Mines to Nangiles the lodes yielded immense quantities of copper ores down to considerable depths. Eastwards, tin ore is more abundant than copper. Hence in proceeding along this series of lodes from west to east the copper ores gradually become less abundant, while the tin ore, although not very abundant, becomes of greater importance. Zinc occurs in the lodes from Nangiles to Wheal Jane but not in great quantity. West Wheal Jane has only been explored to the 70-fathom level.

Distribution of the Subordinate Ores.—The following occurrence of less common ores illustrates their distribution :—

SILVER AND LEAD ORES.—See "Distribution of the Silver and Lead Ores," p. 181.

WOLFRAM.—At Balmynheer Mine (in the parish of Wendron) wolfram occurs in association with zincblende, tin ore, iron pyrites, &c.† Wolfram also occurred in Wheal Druid (eastern part of Carn Brea Mine).‡ In Carn Brea Mine with copper pyrites and mispickel.

Several tons of wolfram have recently been taken from the North Tincroft lode in Tincroft Mine.§ The occurrence of wolfram in East Pool Mine has been referred to above. Some of the wolfram in this mine is traversed by strings of copper pyrites; wolfram ochre also occurred. Wolfram also occurred in Wheal Harmony‖ (on the north of Redruth) and in Poldice¶ and in the main lode at Wheal Busy, where it is associated with tin, copper, and arsenical ores. It occurs at Penzilly, in Breage, mixed with manganese. Wolfram ochre occurs in Wheal Friendship (Gwennap) and Poldice.**

ZINC.—Although occurring in small quantities, this ore has a comparatively wide distribution throughout the area, and is associated particularly with ores of copper, lead, &c. It occurs in Binner Downs Mine, Wheal Crofty, Camborne Vean, South Crofty, Wheal Falmouth, Wheal Andrew, North Roskear, Wheal Towan, Trevaskus, United Mines,†† Wheal Ann,‡‡

* Foster, p. 641. † *Op. cit.*, p. 641.
‡ Garby. *Tr. R. G.S. Corn.*, vol. vi., 1846, p. 84.
§ Information from J. Penhall, manager of Carn Crea and Tincroft Mines.
‖ J. Garby. *Tr. R. G.S. Corn.*, vol. vi., 1846.
¶ Carne, p. 94. ** Klaproth, p. 31.
†† Henwood, Tables, xxxix., lv., xlix., lvi., lxvii., lxi., lxxiii., xxxv.
‡‡ Thomas, p. 50.

Wheal Anna Maria, Swanpool,[1] Wheal Julia,[2] Wheal Lovell, Balmynheer,[3] Nangiles,[4] Trethellan,[5] Violet Seton,[6] Great Wheal Vor (associated with copper pyrites),[7] North Downs,[8] Tresavean, Wheal Briggan.[9] The Crane Mine, Wheal and South Wheal Ellen, Wheal Emily Henrietta, Wheal Music, South and West Wheal Seton, Wheal Tehidy, West Roskear, Wheal Jane, Goonhavern, and in Wheal Jewel, where it is associated with copper and arsenical pyrites.

BISMUTH.—Native bismuth and bismuth sulphide occur with cobalt ores in Dolcoath, Herland Mine, and in Wheal Sparnon (in a cross-course).[10] Bismuth occurred in "Mr. Beauchamp's Mine," Gwennap.[11]

ANTIMONY.—Antimony was found in cross-courses with cobalt ores and iron pyrites in Wheal Falmouth, Herland, and Vor.[12] Antimony is said to have been found at Carclew in Mylor,[13] where remains of ancient mine workings were seen by Mr. Hill.

NICKEL.—In East Pool nickel ore occurred with cobalt ore.[14] In South Tresavean Mine kupfernickel occurred with uranium, silver and lead ores.[15] Sulphide of nickel occurred at Wheal Sparnon;[16] and at Roskrow United Mines (near Ponsanooth) nickel was found with silver, copper and uranium ores and sulphide of iron. In Roskrow United Mines granite is said to occur at 70 fathoms below adit level.

COBALT.—Arseniate of cobalt occurred in a lode containing copper in Dolcoath; it is associated with grey and native silver ore. At Wheal Sparnon, cobalt and arsenic occur in a cross-course.[17] Cobalt ores occur at Wheal Unity[18] and East Pool[19] (see under "Antimony").

MANGANESE.—Wad and other manganese ores occurred in Pedn an Drea Mine, Wheal Tolgus, and Wheal Buckets[20] (near Wheal Sparnon). Manganese also occurred in Wheal Ellen. Grey oxide of manganese has been found at Veryan.[21]

URANIUM.—Pitchblende was found in Tresavean Mine and at Roskrow United Mines (see under "Nickel"). At South Tresavean Mine pitchblende was accompanied by kupfernickel, silver, and lead. The pitchblende of Wheal Buller and Carharrack is said to have been phosphorescent. Uranite also was found in the mines at Ting Tang, Tolcarne, Wheal Gorland, Wheal Unity, Tincroft, Wheal Buller, and Pedn an Drea. Compounds of uranium with phosphorus and copper occurred in South Wheal Basset. Uranium ochre occurred at Carharrack and in Wheal Buller. Pitchblende was found in Ting Tang and Tolcarn Mines.[22] Phillips states that oxide of uranium and pitchblende was found at 30 fathoms from surface in Tolcarn Mine.[23] Uranium ores occurred in Tincroft Mine with wolfram

[1] F. J. Stephens, "On Recent Discoveries of Gold." *Tr. R.G.S. Corn.* 1899.
[2] De la Beche, p. 340. [3] Foster, p. 641. [4] Carne, p. 95.
[5] J. Garby. *Tr. R.G.S. Corn.*, 1847, p. 92.
[6] Brenton Symons. "A Sketch of the Geology of Cornwall," 1884.
[7] R. H. Solly. *Min. Mag.*, vol. ix., 1891, p. 208.
[8] Pryce. *Min. Cornub.*, 1778, p. 136.
[9] Hall's *Mineralogists' Directory*, 1868, p. 39.
[10] J. Garby, *Tr. R.G.S. Corn.*, 1847, p. 86.
[11] W. Borlase. *Nat. Hist. of Corn.*, 1758. [12] Henwood, p. 271.
[13] Courtney, "A Treatise on the Statistics of Cornwall," *6th Ann. Rep. Roy. Corn. Polyt. Soc.*, 1838.
[14] Brenton Symons. "A Sketch of the Geology of Cornwall," 1884, p. 128.
[15] R. Pearce, "Note on Pitchblende." *Tr. R.G.S. Corn.*, vol. ix., 1864, p. 102.
[16] J. Garby. *Tr. R.G.S. Corn.*, vol. vi., 1846, p. 87.
[17] Carne, pp. 105, 113.
[18] J. Garby. *Tr R.G.S. Corn.*, 1846, vol. vi., p 87.
[19] Brenton Symons. "A Sketch of the Geology of Cornwall," 1884.
[20] J. Garby, *Tr. R.G.S. Corn.*, vol. vii., 1847, p. 85.
[21] J. Garby. *Op. cit.*, p. 84. [22] J. Garby. *Op. cit.*, p. 86.
[23] "On the Oxides of Uranium." *Tr. Geo. Soc.*, 1816, vol. iii., p. 112.

and copper.[1] At Dolcoath pitchblende occurred with bismuth and cobalt ores and fluorspar.[2] Uranite (phosphate of uranium and lime) occurred in West Wheal Basset. Uranium ore with arsenical and cobalt ores were found in Herland Mine[3] (Gwinear). Pitchblende occurs at Wheal Basset, Wheal Unity, Wheal Gorland, and Tincroft. Its occurrence at East Wheal Lovell has been remarked by Mr. Cunnack.[4]

GOLD.—Although no deposits containing gold in quantity sufficient to warrant their being worked have been found in the district, its occurrence has been recorded in several places. Its frequent presence as traces in pyrites, &c., accounts for its having been found in the gossans of the lodes of several mines. The gossan of one of the lodes in Nangiles is said to be auriferous,[5] while some gossan from Wheal Gorland when assayed by Captain Hambley was found to contain 6 dwts. of gold and 2 dwts. of silver per ton and also 15·5 per cent. wolfram.[6] Gold was detected in a silver-lead lode at Swanpool Mine and in a lode containing blende and argentiferous galena at Wheal Clinton.[7] Gold was found on a burrow and in a cross-course at Wheal Sparnon[8]; it also occurs in Woolf's cross-course (Breage).[9] According to Mr. Collins gold is also found in traces in copper ores and also in ores of tin, lead, and zinc. Gold has been obtained in greater quantity in alluvial deposits, and Borlase states that nuggets have often been found in tin stream works, particularly those of the parishes of Probus, Kenwyn, St. Stephen, &c. Restronguet Creek[10] and Carnon Valley have yielded nuggets of considerable size, one weighing nearly 2 ozs. The district near Grampound was particularly celebrated for the gold found in the alluvial tin, the miners preserving the gold dust in quills.[11] Carew says that "Tinners do also find little hopps of gold amongst their ore which they keep in quills and sell to the goldsmiths oftentimes with no better gain than Glaucus exchange."[12] Mr. Stephens makes the following remarks with regard to the presence of gold in this region.[13] On the Roscarrack estate, near Falmouth, there is in an old quarry a quartz reef associated with a black siliceous rock. The reef contains pyrites, galena, and blende, which on assay yielded gold, and in some cases over 1 oz. to the ton was found.

In the Red River Valley near Gwithian a siliceous schistose rock is traversed by two sets of joints. The joints contain dusty oxide of manganese which was found to contain gold. At the north cliffs, near Camborne, quartz occurs in large lenticular masses with "green and decomposed chlorite." Some of the quartz is drusy. "Occasionally pure gold can be seen," while assays revealed as much as 1 oz. of gold to the ton. Mr. Stephens also states that gold has been detected in raised beaches. Thus at Godrevy gold was found in a black part of the raised beach, which contained in addition to ½ dwt. of gold per ton, 13 per cent. of oxide of manganese. Raised beaches at Falmouth and Gerrans Bay are stated to have yielded on assay similar results.

[1] Carne, p. 104.

[2] R. Pearce, "Note on Pitchblende in Cornwall," *Tr. R.G.S. Corn.*; vol. ix., 1878, p. 103.

[3] Dr. Berger, "On the Physical Structure of Devonshire and Cornwall." *Tr. Geol. Soc.*, vol. i., 1811, p. 170.

[4] Discussion on Foster's paper, "New Mineral Localities," *Min. Mag.*, 1877, No. 3.

[5] J. Garby, 1848, vol. vii. *Tr. R.G.S. Corn.* p. 90.

[6] F. J. Stephens, "Recent Discoveries of Gold in West Cornwall," *Tr. R.G.S. Corn.*, 1899.

[7] *Op cit.*

[8] J. Garby, "Notice of the Occurrence of Gold in a Cross-Course," *Tr. R.G.S. Corn.*, vol. vi., 1846, p. 265.

[9] J. H. Collins, "Precious Metals in the West of England." *Journ. Roy. Inst. Corn.*, vol. xvi., part i., 1904, p. 103.

[10] W. Henwood, "On Detrital Tin Ore of Cornwall," *Journ. Roy. Inst. Corn.*, 1874, p. 191.

[11] Borlase, p. 213. [12] *Survey of Cornwall*, 1811, first published in 1602.

[13] F. J. Stephens, "Recent Discoveries of Gold," *Tr. R. G.S. Corn.*, 1899.

Mr. Collins* notes Mr. Hambley's statement that gold was found in the West Wheal Tolgus lode in 1854.† Samples of ore from Wheal Jane, West Wheal Jane, and Wheal Tremayne are also said to have yielded on extraction by amalgamation over 2 ozs. of gold per ton.

Distribution of the Lead and Silver Ores.—In the Camborne and Gwennap district it was noticed that the tin and copper lodes of the richest area were more or less suddenly terminated by a line of lodes extending from the United Mines to Wheal Jane, on the south of which no lodes of importance appear. On the eastern margin of the Carnmenellis granite no lodes of importance occur on the south of the Tresavean lodes; and in the Camborne area lodes are absent on the south of the series of lodes that occupy the tract between the Carn Brea and Carnmenellis granites. Proceeding westwards, it is not until the parish of Gwinear is reached, or the western margin of the Carnmenellis granite is followed southwards, that any lodes of importance again appear.

These observations apply equally well to the distribution of the lead-silver as to the tin-copper lodes, with this modification, that in proceeding northwards from the Gwennap district towards Newlyn the lead-silver lodes become of ever-increasing importance. Silver and lead ores occur in a number of the ordinary east and west lodes, as follows :—

At Dolcoath a nearly vertical lode, having a bearing similar to that of the Dolcoath main lode, yielded in the year 1810 from £2,000 to £3,000 worth of silver ore at about the 160-fathom level.‡ This lode contained copper and cobalt. Silver ores occurred in East Pool,§ and argentiferous arsenical iron occurred at Wheal Mary (Redruth) with cobalt ores.‖ At Wheal Falmouth, lead, zinc, and copper occurred in a lode bearing E. 40 deg. N.¶ At Swanpool Mine, near Falmouth, lead, tin, and copper occur in a lode striking E. 28 deg. N. At Wheal Clinton, near Trefusis Point, Falmouth, a little argentiferous lead ore was raised.**

The Crane lode in the Crane and Bejawsa Mine, Camborne, contained lead, copper, zinc, and iron pyrites. Similarly, in the South Wheal Seton Mine the North lode, at the 60-fathom level yielded zinc, copper, and lead; and in North Wheal Seton lead and copper occurred. In West Roskear lead, zinc, and copper occurred in a lode bearing E. 10 deg. N., and in a Caunter lode of the same mine lead, zinc, copper, and tin and some iron pyrites were present. In North Wheal Busy lead and tin occurred in the same lode, and also in North Wheal Jane, where zinc was also present. In Roskrow United Mines, near Ponsanooth, silver, nickel, uranium, and iron occurred. At Wheal Baddern, near Bissoe, a lode yielded galena while in elvan but was unproductive in the killas.††

At West Wheal Towan a lode containing lead, tin, and some iron pyrites, intersects the Tye lode. At South Wheal Ellen (Old Wheal Basset), zinc, copper, and lead occurred. In Wheal Crofty lead, zinc, and copper occurred in the Caunter lode.‡‡ Mr. Collins states that 235 tons of silver ore were

* "Precious Metals in the West of England." *Journ. Roy. Inst. Corn.*, vol. xvi., part i., 1904, p. 103.

† *Rep. R. Corn. Polyt. Soc.*, 1897, p. 100.

‡ J. Carne, "On the Discovery of Silver." *Tr R.G.S. Corn.*, 1818, vol. i.

§ Brenton Symons, "A Sketch of the Geology of Cornwall," 1884.

‖ J. Garby, "A Catalogue of Minerals found in Cornwall." *Tr. R.G. Soc. Corn.*, vol. vii., 1848, p. 82.

¶ Henwood, Table lxvii.

** Information obtained through the kindness of Mr. D. R. Crawfurth Smith, of the Woods and Forests Office, from a Report by Warington Smyth, dated 1857.

†† A. K. Barnet, "On Elvan Courses." *Roy. Poly. Soc. Corn.*, 1873, p. 17.

‡‡ Henwood, Table lvi.

raised from North Dolcoath in 1859-1860, and that in 1827 small quantities of silver ore were raised from Treskerby and North Downs; and in 1878 from Treleigh Consols.* Several of the mines in the Gwinear district as, for instance, Wheal Brook, Wheal Herland, and also Trevaskus and Binner Downs Mines, yielded silver ores. At Tresavean,† Silver Hill, and the New Burra Burra Mine, lead and copper occurred. At South Tresavean Mine native silver and galena with tin ore and kupfer nickel occurred.‡ Silver and copper ores occur in Trumpet Consols Mine, Wendron.§ Galena occurred with copper and arsenical pyrites at Poldory.||

The lead and silver ores sometimes occur in cross-courses as follows:—In Wheal Basset a cross-course contains silver and lead, as also at Gwarnick (the Garras) on the north of Truro,¶ and at Silverwell. In 1720 the Garras Mine yielded lead ore which contained 100 ozs. of silver per ton of lead.**

There is a North and South lead lode in Wheal Falmouth.

IV. Order of Arrival of the Ores.

The granite had consolidated and the elvans were intruded before the lode fissures were impregnated with metalliferous minerals. Assuming that the ores and their characteristic mineral accompaniments were extracted from an igneous magma, the ores must be regarded as being later products of the same magma which gave rise to the elvans, the elvans in their turn being intimately related to the granite.

Many of the silver-lead ores were being deposited after the arrival of tin and copper ores had ceased, yet from their frequent association with the ores of tin and copper it is difficult to assign other than a common mode of origin to both classes of ores. The question of the order of deposition of minerals in the lodes is not quite the same as their order of arrival. The occurrence of copper pyrites moulded on cassiterite is not absolute proof that cassiterite arrived at that place before copper ore, and there appears to be some grounds for the view that the oxidic and sulphidic minerals are practically contemporaneous.

Joseph Carne, in 1822, collected a number of facts which appeared to indicate that a classification of the lodes into distinct epochs of formation was possible. The objections to his method of dealing with the lodes, brilliant as it was for his time, have already been pointed out; but Carne established the general fact that tin ores were deposited before copper ores, and that the latter continued to arrive after the arrival of the tin ore had practically ceased.

Henwood showed that the mineral most commonly found against the walls of lodes is quartz, and occasionally cassiterite, or fluor-

* "Precious Metals in the West of England." *Journ. Roy. Inst. Corn.*, vol. xvi., part i., 1904, p. 115.

† M. H. Klaproth, "Observations Relative to the Mineralogical and Chemical History of the Fossils of Cornwall," 1787. *Translated* by J. G. Groschke, p. 30.

‡ R. Pearce, "Note on Pitchblende in Cornwall." *Tr. R.G.S. Corn.*, vol. ix., 1878, p. 102.

§ J. H. Collins, "Origin and Development of Ore Deposits" *Journ. R. Inst. Corn.*, 1892, p. 66.

|| Klaproth. *Op. cit.*

¶ J. Carne, "On the Discovery of Silver in the Mines of Cornwall." *Tr. R.G.S. Corn.*, vol. i., 1818, p. 120.

** Pryce. *Min. Cornub.*, p. 58.

spar. These are followed by wolfram, oxide of tin, and chlorite. When sulphides, carbonates, or oxidised minerals occur they are generally next in order, and in no case does the cassiterite and wolfram succeed the sulphides.*

Mr. Collins confirms these facts,† and distinguishes two broad classes: (1) the minerals associated with cassiterite, such as quartz, felspar, mica, tourmaline, wolfram, stannite, topaz, apatite, scheelite, fluellite, Tavistockite, churchite, molybdenite; (2) the minerals "which have been observed in immediate contact with cassiterite and mostly deposited upon it," such as quartz, mispickel, pyrites, chalcopyrite, smaltite, blende, bismuth, bismuthinite, hæmatite, limonite, native copper, pitchblende, uranium ochre.‡

The history of the tinstones from Dolcoath, South Crofty, Carn Brea, and Wheal Basset has been described in detail by Dr. Flett, who finds that in all cases the copper ores belong to the later period of infilling, while tin belongs to the earlier,§ and the history of the veins as indicated by the structure of the veinstones is highly complex.

The conclusions to be drawn from the mutual relations of the ores as viewed on a large scale only will here be dealt with.

The similarity in the mode of occurrence of the ores of tin and copper may be thus summarised. Their geographic distribution is practically the same. They are common associates in the lodes, and all the greatest lodes of this district have yielded both tin and copper ores. The differences are as follows: – While tin and copper ores occur in the same lodes, the copper ores occupy a higher position in the lodes than the tin, or else the ores are mixed, but, generally speaking, where both tin and copper ores occur in abundance in a lode, the copper is not far distant from tin ore Again, the copper ore, with a few important exceptions, generally prefers the part of the lode which is in killas. Tin ore occurs either in granite, or in the killas not far from granite; copper ore is sometimes entirely absent from the lodes in the bottom of deep tin mines, *e.g.* Dolcoath. From these considerations only it would be impossible to conclude which ore had arrived first. Indeed, the circumstances point to the fact that copper and tin ores must have arrived together.

The facts advanced by Thomas, Carne, Henwood, and others regarding the intersections of lodes show that a lode containing tin ore may be intersected by a lode containing sulphidic ores. Here, at any rate, is evidence that tin with its characteristic minerals arrived before copper ores. A clear and instructive example occurs in West and Wheal Basset. There the Great Flat lode, which from its apparent mode of origin and its mineral contents is distinguished from the more or less vertical lodes which intersect and

* Table C., p. 214.

† J. H. Collins, "On the Origin and Development of Ore Deposits in the West of England." *Journ. Roy. Inst. Corn.*, 1898, vol. xliv., p. 221.

‡ J. H. Collins, "On Some Cornish Tinstones and Tin Capels." *Min. Mag.*, 1883, p. 121.

§ John S. Flett, "Note on Some Brecciated Veinstones from Cornwall." *Summary of Progress* (H.M. Geological Survey), 1902, p. 155.

heave it. The periods of the arrival of the different ores appear to have overlapped—especially in the case of tin and copper ores. Briefly, the order appears to have been : (1) tin, wolfram, and arsenic and also copper ores* ; (2) copper ores and other sulphides, such as zinc—and possibly some lead and silver; (3) lead and silver ores and carbonates.

V. Local Conditions Influencing Ore Deposit.

Certain rocks appear to be more readily altered and impregnated by ores than others. Thus granite and many elvans very commonly contain tin ore in the vicinity of lodes. On the other hand, some kinds of killas are probably only mineralised with difficulty. The texture of the rock is an important factor. In speaking of the local conditions affecting the deposition of ores the operations which are particularly dependent upon changes of temperature and pressure are not included.

"The connection between bunches of tin and copper ore in fissures and those places where the latter traverse the elvans is, viewing the subject on a large scale, of the most marked kind."† A lode in passing from the killas into elvan may become poorer, but in some cases this is due solely to the fact that the lode is split up into strings and branches in the elvan which, taken together, may be as rich or even richer than the lode in killas.

In the Crenver and Wheal Abraham tin and copper mine the lode sometimes became poor and hard, and was "often divided into branches" in the elvan, and yet the lode appears to have consisted partly of impregnated elvan.‡ In the western part of Wheal Busy, at about 60 fathoms from the surface, near Lobby's shaft, the tin and copper lode is 12 feet wide, but very much broken up in the elvan through which it passes; in the main part of the mine, however, the lode was richest when in elvan.

In Carn Brea Mine the Highburrow lode, as it approached the 310-fathom level (which is at a considerable depth in the granite) changed from a fairly productive tin lode, 15 feet in width, to a poorer and thinner lode, until it cut across an elvan 60 feet in width, where the lode was utterly valueless.§ On the other side of the elvan the lode was only 2 feet wide and became larger in depth but never regained its former productiveness.

Miners, as a rule, say that the softer or "plumb" parts of the rocks (particularly granite and elvan) through which the lode passes are signs of a rich lode.‖ It should be observed that as the elvans were probably still in a heated condition at the time the ores were being deposited important reactions promoting deposition of ore are certain to have taken place near them.

In Nangiles Mine the lodes were rich when they intersected soft (decomposed) elvan ¶ ; thus the Nangiles copper lode was poor in killas but rich in elvan. The country granite of the Great Flat lode in the upper levels of South Condurrow Mine is very soft and kaolinized; especially so in the hanging wall. The numerous lodes in Wheal Basset were all more

* Cassiterite moulded upon mispickel and blende has been found in the deposits of Willeder (Morbihan, France). Fuchs and De Launay. "Traité des Gîtes Mineraux," 1893, p. 139.

† De la Beche, p. 329.

‡ J. Carne, "On Elvan Courses." *Tr. R. G. S. Corn.*, vol. i., 1818, p. 101.

§ Captain White, manager of the mine, states that the lode was quite wrung up in the elvan.

‖ De la Beche, p. 336. ¶ Thomas, p. 17.

or less productive, but were especially rich in the vicinity of elvans.* At Penstruthal mine the tin and copper lode was tried in both the hard and soft (decomposed) parts of the granite; it was poor in the former and rich in the latter.† In the granite at Tresavean Mine the lode is associated with elvan.‡ In East Pool Mine the Engine lode in killas became very rich in tin ores where it intersected elvan.

In Dolcoath Mine the South lode in the upper levels was of greater value where it was in elvan. In West Wheal Seton the old North or main lode situated in killas was much richer in copper ore in the vicinity of elvan than away from it. Many parts of the Great Flat lode in Wheal Basset are simply highly altered elvan impregnated with tin ore. At Wheal Unity Wood large quantities of tin ore were obtained from elvan. Thus at the 60-fathom level an elvan 4 fathoms in width contained tin ore "sprinkled" throughout.§ Another case is that of the well-known Bissoe Bridge elvan, where large quantities of tin ore occurred in the elvan, which can be traced through to the United Mines. The cases of such association of the richer parts of lodes with the elvans near them are bound to be frequent, since the geological conditions of their occurrence is similar.

It appears, as a whole, that the local deposition of the ore in the rocks depends upon the texture and chemical conditions relative to composition of the enclosing rock. In the case of the sedimentary rocks it is not improbable that certain organic minerals contained in them have exercised a considerable precipitating action. Some of the killas beds are distinctly carbonaceous or graphitic; and in some cases mineral pitch (petroleum) has been discovered in the vugs of lodes traversing the killas, *e.g.*, South Wheal Towan, East Wheal Damsel, North Roskear, East Wheal Crofty (at the 120-fathom level in Reeves' lode),‖ Cook's Kitchen, Wheal Unity,¶ Treskerby, Carharrack,** Wheal Jewell, and Poldice.†† In banded sediments forming the country rock of lodes the ore often replaces certain of the bands for a short distance, while the others are unaffected.

At Poldice and Wheal Fortune the lodes were of value in the killas, until a stratum of hard blue killas was encountered in the workings which "cut out" the riches. In Wheal Squire the lodes were valuable in soft light blue killas, until a stratum of hard black killas was encountered in one lode, at the 44-fathom level, and in another lode at the 120-fathom level, with the result that both became poor.‡‡ Similarly, the slate which the miner prefers for tin ore is duller, darker, and harder than that considered good for copper ore.§§ A clay slate "of a very pale greyish hue, passing into dull white," accompanies the richer portions of the copper lodes at Ting Tang, Wheal Virgin, Wheal Jewell, Wheal Unity, and through most of the Gwennap Mines. Some of the lodes passing from this into that of a deep blue colour maintain their productiveness, as at Wheal Fortune (Consolidated Mines) and Ale and Cakes (United Mines); for the most part, however, the lodes are impoverished, as at Wheal Virgin (Consolidated Mines), &c.‖‖ In some parts of Gwennap a reddish slate is regarded with disfavour.¶¶ Wherever tin ore abounds the slates are of uniform character,

* J. Maynard, "Remarks on Two Cross Sections." *Rep. Corn. Poly. Soc.*, 1871, p. 192.

† De la Beche, p. 337. ‡ *Op. cit.*, p. 333. § Henwood, Table lxvi.

‖ *Op. cit.*, p. 214. ¶ J. Garby. *Tr. R.G.S. Corn.*, vol. vi., p. 76.

** Carne, p. 214. Klaproth (1787), p. 32, states that mineral pitch in this mine was found in granite at 45 fathoms from surface.

†† Greg and Lettsom. "Mineralogy," 1858, p. 15.

‡‡ De la Beche, p. 337. §§ *Op. cit.* ‖‖ Henwood, p. 223.

¶¶ Carne. *Tr. R.G.S. Corn.*, vol. iii., 1828.

thickly bedded and deep blue, "with here and there a somewhat greenish tinge, and rather a greasiness or gloss on the surfaces of the cleavage planes."* Generally, the miners find that a change in the character of the country rock is accompanied by a change in the productiveness of the lode.

CONDITIONS RELATING TO GREENSTONE. — Lodes traversing greenstone are hardly ever of great value while in it. Although "the fissures traversing it are often large, and its condition as to the proximity of the granite, the intermixture with elvan dykes, and the intersection of cross-courses is equal to that of the slates with which the greenstones are for the most part associated," they seem as a whole to be unfavourable to the ores of tin, copper, and lead."†

Pryce states that "it is this stratum that is uppermost through great part of the middle of Camborne and Illogan parishes, where many of the principal copper mines are enclosed in it (greenstone or diabase)."‡

CONDITIONS AT LODE INTERSECTIONS.—The lodes are often rich where they intersect one another. The precise effect which such junctions have in promoting deposition of the ores is not certain. In many cases the junction of intersecting lodes affords a good ore body, because there was a considerable opening in that place in which ores could be deposited. The question is complicated, because some of the minerals, such as tin ore, have remained where they were first deposited, while others (copper ore) can migrate under certain conditions with ease, and so are liable to a secondary concentration. "As a leading fact, however, it is understood that the meeting of two lodes at a small angle is productive of good."§ On the other hand, two poor lodes intersecting one another will not have a rich junction.

At Wendron Consols Mine the junction formed by Liddecoat's and Flander's lodes was rich in tin ore.

In West Wheal Damsel the intersection of the New North lode with Tremayne's lode was rich in the deeper parts of the mine.

At Wheal Basset the junctions formed by the intersection of the Great Flat lode by the nearly vertical lodes, which cut through and heave it, were generally productive in tin ore. The nearly vertical lodes do not themselves contain much tin, while below their intersection with the Great Flat lode they are generally very poor.

The Dolcoath main lode at the junction with the South Entral lode is 60 feet wide, and was very rich in that place. The junction of the Caunter lode and the main lode in the same mine was also rich.

CONDITIONS WHERE LODES ARE OF IRREGULAR BEARING.—If a lode changes its bearing slightly in different parts, it is generally found that the richest parts have a common bearing. The relative movement of the walls of an irregular or wavy fissure result in the production of open parts, having a common bearing, which have been filled with veinstone. The closed parts have a common

* Henwood, p. 224. † De la Beche, p. 337.
‡ Pryce. *Min. Cornubiensis*, 1778, p. 75. § De la Beche, p. 334.

but slightly different bearing. Dolcoath main lode affords an instance of this,* and the Great Flat lode may be taken as another instance. Moissenet endeavoured to form an estimate of the amount of movement that had taken place in the walls of the fissure necessary for the formation of the open parts of the lodes in which the ores were deposited. The form of the fissure he regarded as being intimately connected with the hardness of the rocks through which the fissure passed. Taking Henwood's data and basing his calculations on the relations which existed between the angle of general underlie of the lode and the angle of underlie of that irregular part which contained the ore (open part), Moissenet arrived at the conclusion that for most of the lodes of Cornwall a fall of 2·75 to 3·75 metres would produce an opening in the lodes of one metre. It should be remembered, however, that many of the Cornish lodes are the result of in-filling and alteration in the vicinity of a series of close parallel cracks, so that the width of an ore body does not necessarily represent the width of the original open part of a fissure.

VI. DECOMPOSITION AND REDISTRIBUTION OF THE ORES.

Since tin districts are connected with plutonic rocks, it follows that tin-mining districts are situated as a rule only in extensively denuded areas. As a rule also, tin alluvial deposits nearly always occur where there are tin lodes. Simultaneously with the removal of the surface deposits the upper parts of the lodes are being greatly affected by the action of water containing various dissolved substances, such as oxygen, carbon dioxide, and organic acids. The surface water, percolating the crust, penetrates cracks in the lodes and attacks the sulphides and other oxidisable or soluble materials, so that not only is the lode considerably changed in appearance and composition, but redistribution of certain of the minerals takes place. It is upon this principle, taken in conjunction with the assumption that water is able to descend through interstitial spaces and capillary openings in porous rocks to great depths, and reascend through larger cracks or other channels, that various theories have been advanced accounting for the secretion of ores in fissures by the leaching out of metalliferous minerals from the surrounding rocks. In great mining regions this process is supposed to have been particularly stimulated by association with plutonic intrusions, and consequently was mainly active in the contact rocks of the metamorphic aureole.

Some excellent treatises dealing with the origin of certain ore deposits of America have been written from this point of view by American geologists.† Posepny's‡ view is, that from surface to ground water level, there is an active circulation of waters, called the vadose or shallow-underground circulation, resulting from the descent of rain or surface water through the rocks. Below this is the deep-underground circulation pro-

* R. Hunt. "British Mining," 1884, p. 439.

† *e.g.* C. R. Van Hise, "Preliminary Report on the Lead and Zinc Deposits of the Ozark Region." *22nd Ann. Rep. U.S. Geol. Survey*, 1900–1901.

‡ "The Genesis of Ore Deposits." *Tr. Am. Inst. Min. Eng.* (Chicago Meeting), 1893.

moted by differences of temperature in the upper and lower rocks through which it passes. The water, as it descends through capillary openings in the rocks, is gradually warmed, and is able to ascend through other channels. Daubrée* actually supposed that steam emitted from natural vents was produced by actions analogous to those in an experiment carried out by him showing the behaviour of water in passing through a slab of porous material (sandstone), one side of which was heated. Water was able to flow continuously from the cool to the warm part, where it was vaporised. In nature the subterranean water was supposed to find its way down and come in contact with large heated rock masses—intrusive or otherwise. Van Hise† has elaborated the arguments favouring the view that "the greater number of ore deposits are the result of the work of underground waters."

Generally speaking, the distribution of the underground water has constantly changed with the elevation or depression of the district and with denudation. Locally, the arrangement or structure of the rocks, their porosity or imperviousness, and also the extent of fissuring, has a great deal to do with the distribution and circulation of the water, and hence, in all probability, upon the distribution or position of some of the secondarily concentrated minerals. In Cornwall the circumstances do not permit of any extensive application of the principle of circulating waters in regard to the origin of the ores, but it does apply in the case where soluble metalliferous minerals already present in the lode have been dissolved and redeposited in other parts of the lode.

The upper parts of lodes, and especially those lodes containing copper ores, are characterised by the presence of oxide of iron, which is the main constituent of the "Iron Hat" or Gossan, a term by which the weathered ferruginous upper portion of the lode is designated. The iron oxide is derived from copper and iron pyrites by oxidation. Emmons was one of the first to show how sulphides decomposed in this way are dissolved, carried down the fissures, and regenerated; and, indeed, he states that the "native metals and their oxides and chlorides (except, perhaps, gold, tin, and the platinum group of metals)" are generally the result of secondary alteration from sulphides.‡ The general vertical distribution of the ores has been referred to, but in addition to this it will be observed that there is a vertical arrangement of the metalliferous minerals brought about by the action of water, a fact known to miners from early times.§

Emmons distinguishes three zones in the part of the lode affected by percolating waters. An upper zone, near the surface, of recently oxidised ores, gossan, in which may occur some residual masses of sulphide not yet oxidised. Below this is a second zone in which carbonates, oxides, or native metals occur; these are the less soluble or more readily precipitated compounds. Below this is the zone of sulphide-enrichment in which minerals brought in solution are deposited as sulphides. Here occur sulphides, sulph-arsenides, sulph-antimonides, or native metals, in contact with original sulphides of the lodes which have not yet been altered.

* "Geologie Experimentale," vol. i., 1879, p. 241.

† C. R. Van Hise, "Some Principles Controlling the Deposition of Ores." *Tr. Am. Inst. Min. Eng.*, 1900.

‡ S. F. Emmons, "The Secondary Enrichment of Ore Deposits." *Tr. Am. Inst. Min. Eng.* (Washington Meeting), 1900.

§ *e.g.* See Pryce, *Min. Cornub.*, 1778, p. 6.

Van Hise states* that there are three zones. Above the level of ground water there is a belt composed largely of oxides, carbonates, chlorides, and associated products which may contain enriched sulphides. Above and below ground water level is a transition belt, consisting of sulphides rich in valuable metals, such as gold, silver, copper, lead, and zinc, and some oxides. Below this are the "lean sulphides," containing small amounts of valuable sulphurets commonly passing into sulphide of iron.

De Launay† says that near the surface there is a zone of oxides or carbonates, sometimes chlorides. Below this is a zone of argentiferous grey copper with copper glance and native copper. Still lower there is copper pyrites. Vogt‡ has shown that in the San Domingo Mine, in Southern Spain, the amount of copper in the pyrites of these deposits diminishes with depth. He also distinguishes three zones: (1) the oxidised zone, gossan; (2) the small zone containing gold and silver; and (3) below this the principal sulphide zone in which the percentage of copper diminishes with depth.

Penrose§ states that in Arizona the upper parts of copper deposits consist of black and brown ferruginous masses with oxidised copper minerals, such as cuprite, malachite, azurite, chrysocolla, &c.; while at depths varying from a few feet to several hundred feet the deposits are a mixture of copper and iron sulphide in which the latter is in excess. Penrose has also noticed that the decomposition of country rocks in the vicinity of ore deposits is more extensive than in similar rocks in which ore deposits do not occur. "The explanation is, doubtless, in many cases, that the rock has decayed under the influence of the same waters that originally concentrated the ore. When subsequently the ore body is affected by surface influences, sulphuric acid is liberated from sulphide, and carbonic acid from carbonates, as well as other acids from other minerals, and all these materials have an active effect on most rocks."‖

The relation of the underground water to the distribution of the ores has recently received the attention of Mr. Finch,¶ who distinguishes three important zones. Zone I. includes "all depths near the surface in which water is accumulated and conducted to a saturated zone. If there is no saturated zone it terminates with the cessation of downward percolation. It is the 'belt of weathering.'" Zone II. is the zone of discharge. It is the upper part of the belt of saturation of Van Hise, and "embraces that part of the belt of saturation, in any region, which has a means of horizontal escape and discharge. The upper part of Zone II. is very variable. The bottom of Zone II. is the lowest limit of notable movement of water, and is controlled by lowest limit of discharge. If impervious "barriers intervene the bottom of the zone may be the crest of the barrier and much higher than the line of lowest escape." Zone III. The transitory or static zone. "The movement of the water found below the level of the lowest point of discharge is for normal conditions infinitesimal," but convection currents may be set up by heat. Finch believes that Zone III. is rarely extensive, except where there are deep open fissures; and that rocks below 1,000 or 1,500 feet are commonly dry. He divides the upper part of a vein in which secondary enrichment has taken place into two zones: (*a*) the upper is the zone of oxidation, in which are oxides, sulphates, chlorides, bromides, carbonates, silicates, native metals, and loose open veinstone materials; and (*b*) the lower zone (zone of reduction), in which are sulphides, arsenides, antimonides, &c., tungstates, molybdates, &c., and dense veinstone material.

* "Some Principles Controlling Deposition of Ores." *Tr. Am. Inst. Min. Eng.*, 1900, p. 355.

† E. Fuchs and L. De Launay. "Traité des Gîtes Minéraux et Métallifères," vol. ii., p. 233.

‡ "Das Huelva-Kiesfeld in Süd-Spanien und dem angrenzenden theile von Portugal." *Zeit. f. prakt. Geol.*, 1899, p. 241.

§ R. A. F. Penrose, junr., "Superficial Alteration of Ore Deposits." *Journ. Geology*, vol. ii., p. 307.

‖ *Op. cit.*, p. 295.

¶ J. W. Finch, "Aqueous Solutions and Lode Ores." *Proc. Col. Sci. Soc.*, 1904, vol. vii.

These general results have been supported recently by Mr. Hill in regard to Cornwall, who asserts that "before the upper portion (of a lode) shares in the disintegration and denudation that are going on at the surface, it has already parted with its metalliferous contents, which have gone to enrich the lode below. Consequently, according to this view, the enrichment of lodes must be descending at a corresponding rate with surface denudation."* As early as 1778 this general principle was recognised by Pryce, who wrote at some length on the subject.

With regard to the occurrence of cassiterite in the upper portions of lodes, it has occasionally occurred in the gossans of mines wrought for copper in such quantity as to make the outcrop of the lode worth treating for cassiterite. Thus, some of the "backs" of the lodes in the Gwennap district, as well as those near Carn Brea and other places, are typical cases, *e.g.*, Cook's Kitchen, Wheal Unity,† Wheal Daniell, Wheal Spinster, &c. Cassiterite is so insoluble under ordinary conditions that this occurrence is not remarkable, and is explained by the fact that the more readily decomposed minerals have been washed away from a matrix originally carrying cassiterite and decomposable sulphide ores. De la Beche‡ says "it has been found that the percentage of cases is considerable where an iron ochreous substance, named gossan, prevails and copper ore is connected with it, and it may be said that the instances are very rare where copper ore is found in fair quantity in a lode without gossan having been discovered on the 'back.' This gossan is generally mixed with quartz and other mineral substances, among which the oxide of tin frequently occurs." Henwood states that the greatest number of rare and curious minerals are found in the upper parts of lodes, and particularly where gossan is plentiful.§ In Henwood's great work on Cornwall the term "earthy brown iron ore" is very commonly used in the descriptions of the metalliferous contents of the lodes. This no doubt refers to the iron oxides resulting from the decomposition of pyrites. This observer found that in the "superficial" portions of the lodes much iron pyrites (mundic) occurs in East Wheal Crofty, Pennance, United Mines, and Baldhu. Blende occurred in the upper portions of the lodes in the United and Consolidated Mines, Baldhu, Wheal Hope, &c., and that the shallower portions of the lodes yielded earthy black copper ore in gossan in Wheal Jewell and the Consolidated Mines. Native copper and red oxide of copper, with carbonates and arseniates, were also found in Dolcoath, Wheal Buller, Penstruthal, Ting Tang, Wheal Gorland, Wheal Unity, and Wheal Charlotte. Where the lode has a gossan the ferruginous ingredients diminish with depth, while the

* J. B. Hill, R.N. (H.M. Geol. Survey), "The Plutonic and other Intrusive Rocks of West Cornwall in their Relation to the Mineral Ores." *Tr. Royal Geol. Soc. Cornwall*, vol. xii., part vii., 1901, p. 586.

† W. Phillips, "On the Veins of Cornwall." *Tr. Geol. Soc.*, vol. ii., 1814, p. 122

‡ p. 326. § p. 204.

copper becomes more abundant.* The table of the metalliferous contents of the lodes given on page 195 includes those minerals which have been deposited long after the arrival of the ores in the lodes. Of particular interest in this connection are the Cornish pseudomorphs described by Professor Miers. Evidence of the work of meteoric water is plentifully seen in the upper parts of lodes at the present time. Incrustations of basic copper carbonate, carbonate of iron, and pigotite† occur in the drivages of the Entral lode of Dolcoath Mine, to some distance below adit level. These deposits are comparatively recent, as the drivages were made little more than 150 years ago. In the deeper levels the incrustations are not so plentiful, the levels are drier, and the lodes generally cease to bear much oxide of iron. In North Roskear chalcedony occurs as replacement of calc-spar. Observations in Cook's Kitchen Mine confirm the general results as to the dying out of the oxides in depth, although this mine is an old one and the working places have been exposed to the oxidising influence of air and moisture. Chapple's lode, in Cook's Kitchen Mine, consists in the upper parts largely of red oxide of iron, clay, and chlorite, stained by iron oxide. The granite down to below the 100-fathom level is considerably decomposed. Cracks and vugs in it are filled with oxide of iron and clay. Chalybite occurs in small crystals on the sides of the levels, and there are stalactites of pigotite and oxide of iron in the levels about 72 fathoms below adit. The oxide of iron staining diminishes with depth, until at about the 190-fathom level it is only in small quantity. Copper carbonate occasionally occurs as thin incrustations. From the 85-fathom level to the 258-fathom level the lode is traversed by small veins of quartz here and there. From above the 200 to the 345-fathom level, below which the mine was filled with water at the time these observations were made, the lode consists mainly of peach, chlorite, and quartz (or capel), with a little kaolin. Most of the ore of value has, of course, been extracted from the working places, but old reports state that the ores of copper were principally chalcocite and copper pyrites, which were abundant to below the 160-fathom level. The minerals occurring in the upper parts of lodes which may be regarded as being derived by alteration of pre-existing minerals are cuprite, melaconite, native copper, malachite, chrysocolla, chalcopyrite, Redruthite, erubescite, chalybite, limonite, &c., and even mispickel, iron pyrites, copper pyrites, vitreous copper ores, and other minerals: although some of them are not necessarily derived by alteration but may represent original deposit.

The chemistry of the actions by which these compounds are derived has received attention from various writers, who have shown in the form of chemical equations the reactions involved in their production. Iron

* W. Phillips, "On the Veins of Cornwall." *Tr. Geol. Soc.*, vol. ii., 1814, p. 207.

† A compound of mudeseous acid and alumina. See paper by J. K. Creighton "On the Occurrence of Pigotite." *Geol. Mag.*, 1894, p. 223. Also Johnson "On the Constitution of Pigotite." *Phil. Mag.*, 1840, p. 382; and A. A. Julien "On the Part Played by Humous Acids in Ore Deposits, Wall Rock, Gossan, &c." *Proc. Am. Assoc. Adv. Sci.*, 1879, p. 382.

pyrites in the presence of oxygen and water is converted to sulphide of iron and sulphuric acid, which react with the production of ferrous sulphate and sulphuretted hydrogen :—

$$FeS_2 + O_3 + H_2O = FeS + H_2SO_4 = FeSO_4 + H_2S.$$

Iron pyrites is likewise acted upon by the sulphuretted hydrogen of this reaction as follows :—

$$FeS_2 + O_3 + 2\,H_2S = FeS + 2\,H_2O + 3\,S$$

but by further oxidation sulphuric acid is formed, which acts upon iron pyrites :—

$$S + O_3 + H_2O = H_2SO_4.*$$

By reaction between ferrous sulphate, sulphuric acid, and oxygen, the ferric sulphate is obtained :—

$$2\,FeSO_4 + O + H_2SO_4 = Fe_2(SO_4)_3 + H_2O$$

which may react with sulphide of iron with the production of ferrous sulphate again :—

$$FeS + Fe_2(SO_4)_3 = 3\,FeSO_4 + S.$$

By reacting with the oxygen of the air and water sulphuric acid is produced, which is capable of converting ferrous sulphate into ferric sulphate. It was shown by Emmons that the sulphides written in the following order represent the order of the ease with which their decomposition is effected by ferric sulphate :—Iron pyrites (FeS_2) pyrrhotite ($Fe_{11}S_{12}$), copper pyrites ($Cu_2Fe_2S_4$), bornite (Cu_3FeS_3), millerite (NiS), copper glance (Cu_2S), galena (PbS), and zincblende (ZnS).

If copper pyrites or bornite are present the part of the compound consisting of iron sulphide is attacked by ferric sulphate, "leaving Cu_2S as an amorphous, sooty material."† The copper sulphide molecule is next attacked by ferric sulphate, with the production of copper and ferrous sulphate, as follows :—

$$Cu_2S + 2\,Fe_2(SO_4)_3 = 2\,CuSO_4 + 4\,FeSO_4 + S.‡$$

The copper sulphate is soluble, and is carried down the lode until it is decomposed by meeting with iron pyrites, pyrrhotite, or copper pyrites, as follows :—

$$4\,CuSO_4 + 3\,FeS_2 + 4\,H_2O = 2\,Cu_2S + 3\,FeSO_4 + 3\,H_2SO_4 + H_2S$$
$$2\,CuSO_4 + 2\,FeS = Cu_2S + 2\,FeSO_4 + S$$
$$2\,CuSO_4 + Cu_2SFe_2S_3 + H_2SO_4 = 2\,Cu_2S + 3\,FeSO_4 + H_2S.§$$

* W. H. Weed, "Enrichment of Mineral Veins by Later Metallic Sulphides." *Bull. Geol. Soc. America*, vol. ii., 1900, p. 184.

† *Op. cit.*

‡ W. H. Weed gives a formula $Cu_2S + 5\,Fe(SO_4)_3 + 4\,H_2O = 2\,CuSO_4 + 10\,FeSO_4 + 4\,H_2SO_4$. "Enrichment of Gold and Silver Veins." *Tr. Am. Inst. Min. Eng.*, 1900, p. 478.

§ According to Van Hise the reactions involved in the regeneration of copper pyrites may be represented as follows :—

$$CuSO_4 + 2\,FeS = CuFeS_2 + FeSO_4$$
$$\text{or } CuSO_4 + 2\,FeS_2 + O_4 = CuFeS_2 + FeSO_4 + 2\,SO_2.$$

In passing up from lowest level at which copper pyrites occurs it becomes more abundant until bornite becomes an important mineral, thus :—

$$Cu_2SO_4 + CuSO_4 + 3\,FeS = Cu_3FeS_3 + 2\,FeSO_4$$
$$Cu_2SO_4 + CuSO_4 + 3\,FeS_2 + O_6 = Cu_3FeS_3 + 2\,FeSO_4 + 3\,SO_2$$
$$\text{or } CuFeS_2 + CuSO_4 + O_2 = Cu_3FeS_3 + FeSO_4 + SO_2$$

At a still higher level copper glance may be produced as follows :—

$$Cu_2SO_4 + FeS = Cu_2S + FeSO_4$$
$$\text{or } Cu_2SO_4 + FeS_2 + O_2 = Cu_2S + FeSO_4 + SO_2,$$

or according to the equations—

$$CuFeS_2 + CuSO_4 + O_2 = Cu_2S + FeSO_4 + SO_2$$
$$Cu_3FeS_3 + CuSO_4 + O_2 = 2\,Cu_2S + FeSO_4 + SO_2.$$

At still higher levels come oxides and carbonates.

In these reactions copper glance is produced owing to the greater affinity of the copper than the iron for sulphur. Sulphates of lead and zinc may also be produced by similar reactions, and may be precipitated in the same way as sulphides. The carbonates produced in the upper parts of lodes are capable of reduction by contact with sulphides of iron, and Van Hise represents this reaction as follows :—

$$PbCO_3 + FeS = PbS + FeCO_3$$
$$\text{or } PbCO_3 + FeS_2 + O_2 = PbS + FeCO_3 + SO_2.$$

Similar equations represent the reactions forming zinc sulphide. He shows also that zinc sulphide itself is capable of reacting with the sulphate and carbonate of lead, with the formation of lead sulphide and zinc sulphate or carbonate thus :—

$$PbSO_4 + ZnS = PbS + ZnSO_4.$$
$$PbCO_3 + ZnS = PbS + ZnCO_3.$$

With regard to the production of carbonates, oxides, or hydrates from metallic sulphides, Dr. Evans states that free carbonic acid gas is unable to effect this change directly, and as a rule the formation of such compounds from sulphides is accomplished by carbonates.* This is probably owing to the fact that carbonates would be decomposed in the presence of the free acid which would result from this reaction if it were possible.

The production of basic copper carbonate, for instance, above the ground water level, is probably effected by some such compound as ammonium, sodium, or calcium carbonate, thus :—

$$2\,CuSO_4 + 2\,CaCO_3 + H_2O = Cu(HO)_2CuCO_3 + 2\,CaSO_4 + CO_2.$$

The oxide of copper and native copper are produced above ground water level by reactions similar to those represented in the following equations : —

$$2\,CuSO_4 + 2\,CaCO_3 = 2\,CuO + 2\,CaSO_4 + 2\,CO_2.$$

The CuO is reduced to Cu_2O, and may be acted upon either by ferrous sulphate or free sulphuric acid :—

$$Cu_2O + H_2SO_4 = Cu + CuSO_4 + H_2O$$
$$3\,Cu_2O + 6\,FeSO_3 = 6\,Cu + Fe_2O_3 + 2\,Fe_2\,(SO_4)_3$$
$$\text{or } 3\,Cu_2O + 2\,FeSO_4 = 4\,Cu + Fe_2O_3 + 2\,CuSO_4.$$

The oxidation of the iron salt is carried out by abstraction of the oxygen from the copper oxide, which is reduced in consequence, and, as pointed out by Penrose, this reaction may take place at comparatively considerable depths below the oxidised zone in the lodes.

In the oxidised zone the production of oxides of iron which characterises the gossan takes place according to the equations :—

$$12\,FeSO_4 + 6\,O + 2\,H_2O = 4\,Fe_2(SO_4)_3 + 2\,Fe_2O_3H_2O$$

or to limonite ($2\,Fe_2O_3\,3\,H_2O$).

Ferric sulphate may also be oxidised to limonite and free acid.

The reactions involved in the decomposition and regeneration of the rarer metals are capable of expression in the form of equations. The question of secondary deposition of silver has received attention from Vogt,† who shows how native silver is a secondary product derived from silver glance. Weed shows how silver sulphate acting upon copper sulphide results in the production of silver sulphide and copper sulphate. Similarly, pyrites decomposes impure pyrites containing antimony, arsenic, and silver, with the production of antimony sulphide. Native silver may result from the action of ferrous sulphate on silver sulphate, thus :—

$$Ag_2SO_4 + 2\,FeSO_4 = Ag_2Fe_2(SO_4)_3.$$

According to Bischoff, silver sulphide acted upon by steam yields native silver :—

$$4\,Ag_2S + 4\,H_2O = 8\,Ag + H_2SO_4 + 3\,H_2S$$

* J. W. Evans, *Min. Mag.*, vol. xii., 1898–1900, p. 377.

† "Ueber die Bildung des gediegenen Silbers, durch secundär processe aus Silberglanz und anderen Silbererzen." *Zeit. f. Prakt. Geol.*, 1899, p. 113.

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The reaction represented by this equation is, however, not an accompaniment of surface action.*

The presence of gold in gossan, in rather larger quantity than is found at greater depths in the lodes, is accounted for by the action of ferric and ferrous sulphates. The gold is dissolved by ferric sulphate and precipitated by ferrous sulphate, a sulphide, a native metal, or by organic matter. Many sulphides contain gold in the form of a mechanical mixture of free gold and the sulphide. The decomposition of the sulphide results in the formation of oxide of iron, in which the gold remains.

The variety of ores in the upper parts of the lodes is accounted for by the complicated set of reactions resulting from the effect of surface water containing a few simple substances in solution. The depth to which these effects extend in the Cornish mines cannot be stated with accuracy. With regard to the gossan, the tabulated statements of the lodes in the different mines of Cornwall show that oxidising influences in the Camborne region have been at work from surface to a depth of at least 1,000 feet, and in all probability below this. The distribution of this oxidised zone is by no means regular, so that no definite assertions can be made.

VII. Minerals of the Ores.

Cassiterite.—(SnO_2) in the lodes presents a variety of structures and modifications, occurring in minute embedded grains (Zinn-zwitter), or in small or large crystals either embedded or encrusting (Zinn-grauper), and as the fibrous variety known as wood—or Toad's-eye tin. Wood-tin occurred in some abundance in the Metal lode in Wheal Vor in scattered grains, small isolated masses, or in veins of varying but small dimensions, at a depth of about 180 fathoms from surface.† In this mine the tin ores were all obtained from the lode in killas, which in some places, in 1867, was worth £1,000 per cubic fathom‡; in granite, the lode was a mere string and was almost barren of tin.§ As seen by the naked eye, the tin ore commonly occurs filling or encrusting the walls of minute cracks in the granite or killas, or it may form small strings in quartz tourmaline rock, or in quartz with chlorite, and not infrequently in masses consisting almost entirely of tinstone and chlorite with a little quartz and tourmaline. Occasionally, it is abundant in china clay or occurs in decomposed granite in the neighbourhood of the lode. The tin ore frequently occurs in the same crack with arsenical and copper pyrites, but in these cases crystals of tin are idiomorphic and were the first of the minerals to crystallise. In brecciated masses of lodestuff the tin ore is clearly seen to be associated with the earlier fragments of the brecciated material, and is itself frequently broken and crushed. Wolfram, with occasionally arsenical and copper

* See "Elements of Chemical and Physical Geology," by G. Bischoff. Translated by B. H. Paul, 1859, vol. iii., p. 536.

† W. Argall, "On the Occurrence of Wood-tin at Wheal Vor." *Journ. Roy. Inst. Corn.*, vol. iv., 1873, p. 255.

‡ Charles Thomas, "Mining Fields of the West," 1867, p. 24.

§ Carne, p. 93.

pyrites, with quartz, tourmaline, chlorite, and sometimes fluorspar, appear to be the principal minerals associated with the tinstone. Cassiterite crystals taken from the 314-fathom level at Dolcoath in 1878 are very fine and of a jet black colour "shading into brown with adamantine lustre." Some associated with limpid fluorspar and chlorite from the Wheal Harriet part of Dolcoath were deeply striated on the prism faces. In Great Wheal Vor jet black crystals of cassiterite show polysynthetic twining, while others are brown and often highly modified, and occur with chlorite and sometimes limpid crystals of apatite. Blende, copper pyrites, mispickel, iron pyrites, and pearl spar (Dolomite) also occur with tinstone in this mine.* An extensive series of tinstones are exhibited in the Museum at Jermyn Street.

The following table enumerates the other metallic products, together with their mineral associates:—

—	Mine.	Accompanied by.	Remarks.	Authority.†
Stannite	Carn Brea	...	Sparingly	Garby, p. 85.
	South Crofty	...	...	
	East Pool	...	In some quantity	
	Scorrier Mine	...	In small quantity	De la Beche, p. 584.
	Barrier Mine (Gwennap)	...	...	Hall, *Min. Directory*, 1868, p. 38.
Copper pyrites	Tolgus, Wheal Jewell, Dolcoath, Cook's Kitchen, North Roskear, East Wheal Crofty, East Pool, &c., &c.	...	One of the principal ores of the mines	
	Consolidated Mines	Iron pyrites	...	Catalogue of Mineral Collection at Jermyn St., 1864.
	Tresavean	Fluorspar	...	
	Carn Brea	Specular iron ore and carbonate	...	
	North Roskear	Fluorspar	...	
	Buller	"	...	

* R. H. Solly. *Min. Mag.*, vol. ix., 1891, p. 207. See also William Phillips, "On the Oxide of Tin." *Tr. Geo. Soc.*, 1814, vol. ii., p. 336. Also "Specimens of British Minerals from the Cabinet of Philip Rashleigh," 1797.

† The references to Garby and Rashleigh relate to the following:— J. Garby, *Tr. R.G.S. Corn.*, vol. vii., 1848, p. 71, *et seq.* P. Rashleigh, "Specimens of British Minerals selected from the Cabinet of Philip Rashleigh," 1797.

—	Mine.	Accompanied by.	Remarks.	Authority.
Vitreous copper ore	Carn Brea, East Basset, South Basset, Trethellan, Tresavean, Dolcoath, Wheal Jewell Abraham	...	Abundant in lodes rich in copper	See "Observations relative to Mineralogical History of the Fossils of Cornwall," Klaproth. Tr. by Groschke, 1787, p. 26.
Redruthite -	Carn Brea -	Copper pyrites, wolfram, tin, chlorite, quartz, &c.	In upper parts of lode	R. H. Solly, *Min. Mag.*, 1891, vol. ix., p. 199.
	Camborne Vean, Cook's Kitchen, Wheal Buller	...	...	
Grey copper ore	Great Work -	Copper pyrites, tin ore	In South Wheal Breage lode	B. Kitto, *Rep. Corn. Poly. Soc.*, 1869, p. 48.
	Tresavean Mine	...	...	Garby, p. 88.
	Cook's Kitchen, Tincroft, Condurrow, Tresavean, Carharrack, South Basset	...	...	
Bornite, Erubescite	Carn Brea, Dolcoath, &c.	With copper pyrites	Common in Carn Brea	
	Wheal Buller,	...	...	
	North Wheal, Fortune	...	...	
	Wheal Falmouth	...	...	J. Mitchell, *Tr. R.G.S. Corn.*, vol. iii., 1828, p. 338. Henwood, Table lxvii.
	Camborne Vean, &c.	...	...	
	South Tolgus	...	...	
Indigo copper	Carn Brea -	...	...	Garby, p. 88.
Arsenate of copper	Wheal Buller and Beauchamp	...	...	Henwood, Table lviii.
	Ting Tang -	...	...	
	Carharrack	...	...	
	Gorland -	(See Tile ore and red oxide of copper)	...	Garby, p. 90.
	Pedn an Drea	...	...	A. W. Tooke, *Min. Rev.*, 1836, p. 236.

—	Mine.	Accompanied by.	Remarks.	Authority.
Arsenate of copper—*cont.*	Herland -	...	...	Symons, "A Sketch of the Geology of Cornwall," 1884.
Wood copper	Wheal Unity-	...	...	Carne, p. 93.
Libethinite (phosphate of copper)	South Wheal Frances	...	...	
Condurrite or pitch copper	Condurrow, Wheal Druid	...	Analysis by Dr. Faraday in 1827. Cu. 60·5 per cent., As. 1·51, As_2O_3 25·94, S. 3·06, Water 8·99.	Garby, *Tr. R.G.S. Corn.*, 1846, vol. vi.
Tile ore -	Wheal Gorland	Chlorite, blue and green copper carbonate, arseniate of copper and iron, and native copper	...	W. Phillips, *Tr. Geol. Soc.*, vol. i., 1811, p. 30.
	Wheal Jewell	Fluorspar	...	*Op. cit.*
	Tolcarne -	...	...	
	Tincroft -	Copper ochre, red crystallised copper ore, and malachite	Decomposing	Rashleigh, p. 17.
	Wheal Unity	...	...	
Cuprite- -	Carn Brea -	Chrysocolla	In a small vein	W. Semmons, *Min. Mag.*, vol. ii., 1878.
	Gorland -	...	...	
	South Frances	...	...	
Red oxide of copper	Ting Tang -	Vitreous copper ore and earthy brown iron ores	...	Henwood, Table lx.
	Wheal Buller, Treskerby	With native copper	...	Catalogue Min. Collection, 1864.
	Wheal Damsel	...	...	Carne, p. 121.
	Tincroft -	Native copper	...	W. Phillips, *Tr. Geol. Soc.*, vol. i., 1811, p. 31.
	Dolcoath -	With black oxide	...	
	West Wheal Virgin	Vitreous and native copper	In a cross course ("Tiddy's")	Henwood, p. 92.

—	Mine.	Accompanied by.	Remarks.	Authority.
Red oxide of copper—*cont.*	Wheal Gorland	Fluorspar, vitreous copper, black oxide of copper, arseniate of copper, mispickel, quartz, and native copper	In the Muttral and Great Gossan lode about 66 and 86-fm. level in Gossan	W. Phillips, *Tr. Geol. Soc.*, 1811, p. 23.
Capillary red oxide of copper	United Mines	Native copper	In a cross-course ("Tiddy's")	Henwood, p. 270.
Green carbonate of copper	Ting Tang -	Blue carbonate, copper pyrites, and vitreous copper	...	Henwood, Table lx.
	Dolcoath -	Red oxide of copper	...	Catalogue Min. Collection, 1864.
	Buller - -	...	...	Henwood, p. 214.
	Wheal Virgin	With grey copper ore	...	Klaproth (*op. cit.*), p. 28.
	Carharrack -	...	...	
	Binner Downs	Blue carb. copper	...	Henwood, Table xxxix.
	Wheal Gorland	(See Tile ore)	...	
	Trefusis -	...	...	
Blue carbonate of copper	Basset, Buller, Ting Tang	...	...	Garby, p. 89.
	Virgin - -	...	...	Klaproth (*op. cit.*), p. 28.
	Carharrack -	...	...	Klaproth (*op. cit.*), p. 28.
	East Pool -	...	...	W. Borlase, *Nat. Hist. of Corn.*, 1757, p. 198.
	Gorland	...	...	
	Cook's Kitchen	Ochre -	...	Rashleigh, p. 22.
	Nanterrow Mine (Gwithian)	...	In the gossan	
	Dolcoath -	...	Ripple marked encrustation on the walls of old levels in the Entral lode	
	Wheal Trefusis	...	...	
Tennantite -	Tresavean	With Bornite	...	

—	Mine.	Accompanied by.	Remarks.	Authority.
Tennantite—*cont.*	Wheal Jewell, West Jewell, Dolcoath, North Roskear, Cook's Kitchen, Tincroft, Carn Brea, Wheal Unity, Trevaskus, &c.	...	...	J. H. Collins, *Min. Corn. & Devon*, 1871.
Chrysocolla -	Ting Tang -	Copper pyrites, vitreous copper	(See Cuprite)	Henwood, Table lx.
	Gorland -	...	...	Hall, *Min. Directory*, 1868, p. 39.
Native copper	Cook's Kitchen	...	Several tons obtained	Pryce, *Min. Cornub.*, 1778.
	Wheal Virgin	...	...	M.H.Klaproth, "Observations on Mineralogy of Cornwall," 1787, p. 25. Tr. by Groschke.
	Carn Brea -	...	In large quantity	Garby, p. 88.
	Wheal Gorland	...	(See Red oxide of copper and tile ore)	
	Carharrack -	...	...	
	Poldory -	With red vitreous copper ore	...	Klaproth (*op. cit.*), p. 26.
	United Mines	...	...	Rashleigh, p. 31.
	Tincroft, Dolcoath	Vitreous copper	In small quantity in strings	Henwood, p. 65.
	Wheal Music	...	...	
	Consolidated, United, West Wheal Virgin	Oxide of copper	In a cross-course ("Tiddy's")	Henwood, p. 92.
	Treskerby -	...	...	Carne, *Tr. R.G.S. Corn.*, vol. vi., 1846, p. 26.
	South Frances	(See Red oxide of copper)	...	
	Condurrow Mine	Clayey, priany load	In a pipe 18 ft. long, 8 ft. high, 3 in. to 5 in. wide	E. W. W. Pendarves, *Tr. R.G.S. Corn.*, vol. iii., 1828. (See also De la Beche, p. 591.)
	Tresavean Mine	...	Pseudomorph after cuprite	H. A. Miers, *Min. Mag.*, vol. xi, 1897.

—	Mine.	Accompanied by.	Remarks.	Authority.
Mispickel -	In many mines in the district	...	Common in lodes. Its presence necessitates the roasting of ores	
	Dolcoath -	Cobalt and nickel ore	...	Catal. Min. Coll., Jermyn Street, 1864.
	Great Wheal Vor	Blende, copper pyrites, iron pyrites, tinstone	...	R. H. Solly, *Min. Mag.*, vol. ix., 1891, p. 208.
Leucopyrite -	Pedn an Drea, &c.	...	...	C. Le Neve Foster, *Min. Mag.*, 1877, No. iii.
Oxide of arsenic	Wheal Sparnon	...	In a cross-course	Garby, *Tr. R.G.S. Corn.*, vol. vi., 1846, p. 86.
Native arsenic	Dolcoath -	Cobalt ores	...	Garby, p. 86.
Wolfram -	Pedn an Drea, &c.	...	(See under "Distribution of Ores," p. 178)	
Scheelite -	East Pool Mine	...	As partial replacement of wolfram. At Wheal Maudlin, near St. Austell, Miers records wolfram after scheelite	J. H. Collins, "On Cornish Mineral Localities," *Min. Mag.*, 1878, p. 92. (*Min. Mag.*, 1897)
Phosphate of lead	Wheal Falmouth	Carb. and phosph. of iron	...	Henwood, Table lxvii.
	Wheal Rose -	...	...	
Arsenate of lead	Wheal Rose -	...	(See Phosphate of lead)	
	North Downs	...	...	
	Wheal Unity	...	...	Henwood, p. 87.
	Gorland -	...	...	A. W. Tooke, *Mining Rev.*, 1836, No. viii., p. 253.
Carbonate of lead	Wheal Rose (Helston)	(See Phosphate of lead)	Some crystallised on hæmatite	
Galena -	...	(See Distribution of Silver-Lead ores p. 181)	...	

—	Mine.	Accompanied by.	Remarks.	Authority.
Native silver	Wheal Basset	Galena ...	In cross-course near its intersection with a lode	Carne, *Tr. R.G.S. Corn.*, vol. i., 1818, p. 123.
	Herland -	Arseniate of silver, vitreous and capillary silver ore, mispickel, and iron pyrites	In a cross-course striking N. 30 deg. W. Only rich near a copper lode. £8,000 worth of silver ore	Carne, *Tr., R.G.S. Corn.*, vol. i., 1818, p. 123.
	Dolcoath -	Vitreous and red silver ores. Some associated with chenocoprolite	South Entral lode	Henwood, p. 65.
	South Tresavean	Argentiferous galena, kupfernickel, and pitchblende	Found in 1863	R. Pearce, "Note on Pitchblende," *Tr. R.G.S., Corn.*, vol. ix., 1864-78, p. 102.
Vitreous silver (glance)	Dolcoath, Herland, Basset, South Basset	(See under Native silver)	...	
Red silver ore	Dolcoath -	(See under Native silver)	Some crystallised on arsenical pyrites	
Chloride of silver	North Dolcoath	Horn silver, crystallised and massive	8 tons 6 cwts. in 1858.	Mineral statistics
Blackjack	...	Copper and lead ores, &c. (See Distribution of ores, p. 178)	...	
Bismuthinite	East Pool -	...	Acicular coating. Needles lying on face of joint	
	Herland -	Cobalt ores and native bismuth	...	Garby, p. 86.
	Dolcoath -	Native bismuth. Some native bismuth associated with fluorspar	...	Garby, p. 86.
	Sparnon ...	Native bismuth and cobalt ores	...	Garby, *Tr. R.G.S. Corn.*, 1846, p. 86.

—	Mine.	Accompanied by.	Remarks.	Authority.
Bismuthinite —*cont.*	Beauchamp -	Cobalt ore	...	W. Borlase, *Nat. Hist. of Cornwall*, 1758, p. 129.
Native bismuth	...	(See under Bismuthinite)	...	
Stibnite -	Dolcoath -	(See under Red silver ore)	...	
	Falmouth -	Cobalt ore and iron pyrites	In a cross-course	Henwood, Table lxvii.
	Herland -	Cobalt ore, iron pyrites, and quartz	In a cross-course	Henwood, p. 271.
	Wheal Vor -	Cobalt ore, iron pyrites, and quartz	In a cross-course	Henwood, p. 271.
Cobalt bloom	Wheal Unity-	...	...	Garby, p. 87.
	Sparnon -	...	...	
Smaltite (tin, white cobalt)	Dolcoath -	Native arsenic	...	Garby, p. 87. (See also Pryce, p. 50.)
	Sparnon -	...	In veins and small bunches (one mass weighed 1,333 lbs.)	Garby, p. 87. Carne, p. 113.
	Elizabeth -	...	...	Hall, *Min. Directory*, 1868, p. 50.
Cobalt ore -	Wheal Beauchamp	(See under Bismuthinite)	...	
	East Pool -	...	...	Symons, "A Sketch of the Geology of Cornwall," 1884, p. 128.
	South Crofty (Dudnance)	...	...	Pryce, p. 50.
	Wheal Gal (Ponsanooth)	With "cal" (Gossan) and tin ore	...	Pryce, p. 50.
	Falmouth and Vor	(See under Stibnite)	...	
Kupfernickel	...	(See Distribution of ores p. 179)	...	
Sulphuret of nickel (Millerite)	Wheal Sparnon	(See under Distribution of ores, p. 179)	...	Garby, *Tr. R.G.S. Corn.*, vol. vi., 1846, p. 87.
Molybdenite ("Molybdenum")	Wheal Crofty, Wheal Unity, Gorland	...	...	Gilbert, *Hist. of Corn.*, vol. i., 1817, p. 268.

—	Mine.	Accompanied by.	Remarks.	Authority.
Wad -	Wheal Buckets (near Sparnon)	...	...	Garby, p. 85.
	Wheal Tolgus		...	
	Pedn an Drea		...	
	Sparnick -	With small veins of galena	In a vein 3 in. wide in elvan	A. K. Barnett, "On Elvan Courses," *Roy. Corn. Poly. Soc.*, 1873, p. 17.
Pitchblende -	...	(See under Distribution of ores p. 179)	...	
Uranite -	...	(See under Distribution of ores p. 179)	...	
Johannite -	South Basset	Other uranium ores	Lemon and sulphur yellow	Garby, p. 86.
Barytes -	Consolidated Mines and Wheal Friendship	...	...	Symons, *Gazetteer of Corn.*, p. 212.
Specular iron ore	Wheal Beauchamp	...	...	Garby, p. 83.
	Tincroft, Carn Brea, Tresavean	...	...	J. H. Collins, *Min. Loc.*, 1871.
Magnetic iron ore	Wheal Harmony worked at Treluswell and found in other places	...	...	Garby, p. 82. De la Beche, p. 618.
Limonite -	...	Common in many mines	...	
Arsenate of iron	Wheal Druid, Gorland	...	...	Garby, p. 84.
Carbonate of iron	Wheal Beauchamp	(See under Phosphate of lead)	Common as a late incrustation in old levels and working places, *e.g.*, Cook's Kitchen	
	Tincroft -	...	...	
	Dolcoath -	...	...	
	Wheal Towan	...	...	Hall, *Min. Directory*, 1868, p. 32.
	Carn Brea -	...	...	H. A. Miers, *Min. Mag.*, vol. xi., 1897, p. 266.
	Wheal Basset	Tin and copper	..	

—	Mine.	Accompanied by.	Remarks.	Authority.
Phosphate of iron	...	(See under Phosphate of lead)	In Wheal Jane crystallised on iron pyrites	
Sulphuret of molybdena	In Gwennap, Wheal Friendship, Wheal Gorland, and Wheal Unity	...	...	Garby, p. 85.
Native sulphur	Nangiles -	...	...	Garby, p. 92.

Cornish Pseudomorphs.*

Chalcopyrite after bismuthine, bournonite, calcite, Redruthite, tetrahedrite.

Redruthite after galena, iron pyrites, erubescite.

Erubescite after chalcopyrite and Redruthite.

Iron pyrites after calcite, barytes, fluor, pyrrhotite, quartz.

Chalybite after fluor, calcite, barytes, dolomite, pyrites, bismuthine.

Limonite after fluorspar (Cook's Kitchen).

Professor Miers describes a hollow drusy pseudomorph of the form of mispickel in a matrix of chlorite and accompanied by a later deposit of chalybite and tarnished erubescite (Carn Brea Mine).

* H. A. Miers, "On some British Pseudomorphs." *Min. Mag.*, vol. xi., 1897.

CHAPTER XVII.

THE MINES.

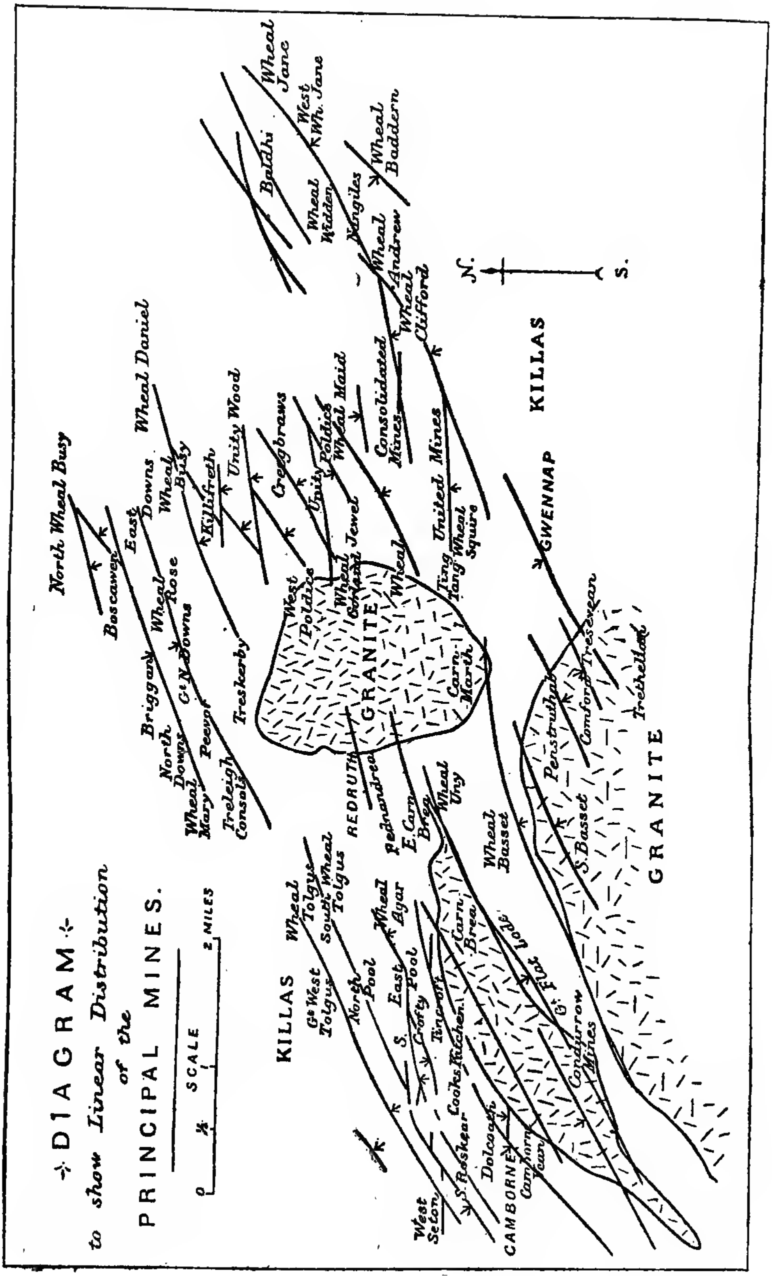
I. Linear Distribution of the Principal Mines.

The principal mines are situated side by side along important mineralised belts or zones, so that in a diagrammatic manner the mines on any particular zone can be represented on a map by a single line. (Fig. 21.) Thus in the Camborne district a line on the northern margin of the Carn Brea granite represents the important lode belt upon which are situated—Camborne Vean Mine, Dolcoath, Cook's Kitchen, Tincroft, and Carn Brea Mines. A line parallel with it but further north may represent the important lodes of South Roskear, South Crofty, and East Pool Mines. The Great Flat lode on the southern margin of the Carn Brea granite, and the vertical series which intersect it, can in like manner be diagrammatically represented as an important mineral belt by two lines upon which are situated South Condurrow Mine (and Wheal Grenville), West Frances, West Basset, South Carn Brea (and Wheal Basset), and Wheal Uny. Similarly, in the Gwennap district, the important mines are situated along a line extending from the United Mines through Wheal Clifford, Wheal Andrew, Nangiles, Wheal Widden, and West Wheal Jane to Wheal Jane. A branch* of this series of mines runs from the Consolidated Mines to Wheal Andrew, and another branch* runs through Ting Tang to the United Mines. Wheal Damsel, Wheal Maid, and Todpool are again in linear arrangement. North of this are several series of lodes upon which important mines are situated, as follows:—Wheal Jewell and Poldice; Wheal Gorland, Unity, and Creegbraws; West Poldice; Unity Wood;* Killifreth.* These lines are short. Near Scorrier Gate there is a mineralised zone along which Treskerby, Scorrier Old Mine, Great Wheal Busy, and Wheal Daniell are situated. North of this there are two more series of important mines —New Treleigh Consols, Wheal Peevor, Great North Downs, Wheal Rose and East Downs; and Wheal Mary, North Downs, Wheal Briggan, and Boscawen.

Each of these zones is made up of several important lodes which have a bearing similar to that of the zones themselves. Hence these lines represent the linear arrangement of the principal mines, the position of the principal mineralised belts or zones, and the bearing of the principal lodes of which the belts are composed. In this manner the confusion which is sure to arise from any attempt to work out the lode systems by consideration of the particulars of individual lodes is largely eliminated. It should be

* *See* Note at the end of this Section.

FIG. 21.



observed that the country separating these great lode series is also fissured and mineralised, but the importance of the lodes in it is less.

Reference to the diagram or geological map shows that these lode zones can be divided into two main systems, according to their

directional characters, which may have been determined by the nature of the folding in the sedimentary rocks, produced by the pre-Devonian and post-Carboniferous movements. In the particulars given above, those series marked with an asterisk (*) have a bearing of a few degrees north of east, and in some cases they appear to fault the other series, which has a bearing of about E. 30 deg. N. The latter make up the more important system.

II. Particulars Relating to the Mines.

Miscellaneous information relating to individual mines may be obtained in the following publications, much of which it is unnecessary to reproduce; so that the descriptions which follow are largely confined to unpublished information, together with scattered facts not already referred to in the previous pages :—

The *West Briton* (since 1805).

The *Engineering and Mining Journal* (since 1830).

The *Mining Review*. "Survey of Carnmenellis District," vol. iii., 1835. ("Descriptive notice of the Consolidated and United Mines," vol. iii., 1835). "The Mining District of Redruth," vol. ii., 1832.

1819. Thomas, Richard, "Report on a Survey of the Mining District from Chacewater to Camborne."

1843. Henwood, W. J., "On the Metalliferous Deposits of Cornwall and Devon." *Tr. R.G.S. Corn.*, vol. v.

1843. Watson, J. Y., "A Compendium of British Mining, with Statistical Notices of the Principal Mines in Cornwall."

1860. Pike, J. R., "Britain's Metal Mines."

1862. Salmon, H. C., "The Seton Mining District." *Mining and Smelting Magazine*, vol. ii., pp. 277 and 332. Also descriptions of prominent mines, pp. 74, 84, 86, 140 and in vol. i., pp. 314, 384.

1863. "The Condurrow District." *Mining and Smelting Magazine*, vol. iii., p. 82.

1865. Spargo, T., "The Mines of Cornwall and Devon."

1867. Thomas, C., "Mining Fields of the West."

1873. J. H. Collins, *Inst. Mech. Eng.* "On the Mining Districts of Cornwall and West Devon."

1874. Maynard, J., "Mines of the Illogan District." *42nd Ann. Rep. Roy. Corn. Poly. Soc.*, p. 84.

1876. ———"Note on a Cross Section from Cook's Kitchen to Wheal Emily Henrietta." *Rep. Miners' Assoc. Corn. and Devon*, p. 65.

1884. Symons, Brenton, "Gazetteer of Cornwall."

1890. Collins, J. H., "Origin and Development of Ore Deposits in the West of England." *Journ. Roy. Inst. Corn.*, p. 109.

1892. ——— Do. do. p. 111.

1893. ——— Do. do. p. 327.

1897. ——— Do. do. p. 195.

In the following particulars relating to the mines precedence has been given to those which are now working. The abandoned undertakings, however, do not imply the exhaustion of the local mine-fields, and it may be regarded as certain that many will be again opened up in the future.

The Active Mines.

Wheal Basset.—There are a number of lodes in this sett, but in recent years the ore has been obtained principally from the *Great Flat lode*, which

has been explored to a depth of 260 fathoms from adit measured vertically. The lode in some places is of enormous width. The Flat lode was first discovered in 1876 in this mine, and during the following years it was extensively explored. From September, 1883, to October, 1884, over 17,000 tons of ore were taken from the stopes, averaging 34 lbs. of black tin per ton. From October, 1884, to May, 1885, 10,809 tons were raised, averaging 46 lbs. per ton; and in 1887, 400 to 450 tons were raised weekly, yielding 7 tons of black tin a week. The lode is traversed by numerous quartz strings. It consists mainly of blue peach, which in some places is brown or dull red owing to presence of ferruginous material. In many cases the peach shows the original structure of the granite from which it was formed. The other lodes have yielded copper ores to a depth of about 150 fathoms from surface. Between the years 1815 and 1833, 17,416 tons of copper ore yielding 577 tons of metallic copper, were raised.*

The Great Lode underlies north and varies in width from 2 to 7 feet. At the 120 and 130-fathom levels the lode consists of quartz, flucan, tin and copper ores, and a good deal of ferruginous matter.

Giesler's Lode is situated on the north of the Great lode and underlies north. Near the Old Sump shaft it is 1 to 2 feet in width at the 120-fathom level and contains both tin and copper ore.

Paddon's Lode.—Situated north of Giesler's lode and underlies north. At the 120-fathom level near the Old Sump shaft the lode contains copper ore and is 1½ feet in width.

Paddon's North Branch.—Varies in width from 1¼ to 1 foot and yielded good copper ore.

Theaker's Lode branches off from the Great lode on the south side below adit level. It has a southerly underlie.

William's South or Caunter Lode.—Nearly vertical. It crosses William's lode. At the 110-fathom level it is 1 foot wide and yielded copper ore.

William's Lode.—It has a good gossan and underlies S. 10 deg. It is about 4 feet in width, and consists largely of quartz, clay, and ochreous materials.

Vivian's Lode is north of the New lode, which is situated below Vivian and Paddon's lodes. It underlies south and yielded copper ores.

North Basset Lode.—Situated on the north of Vivian's lode and explored for copper ore to considerable depth. At the 185-fathom level it is 18 feet wide and yielded tin ore to the value of £10 per cubic fathom.

North Lode.—Situated north of the North Basset lode. It underlies 23 deg. N. and varies from 1 to 12 feet in width. The lode has yielded good copper ores and consists of quartz, peach, and killas, with some mundic.

Carne† described the mode of occurrence of silver in Wheal Basset.

A grey silver ore accompanied by galena which did not itself contain much silver, yielded as much as 600 ozs. of metallic silver per ton of stuff. The ore was found in a cross-course about 4 inches in width, near the place where it intersects a copper lode. At 6 feet on either side from the line of intersection of the cross-course and the lode the cross-course ceased to contain silver ore.

Carn Brea and Tincroft United Mines.—The sett includes Tincroft Mine (formerly Wheal Fanny), Carn Brea Mine, and Wheal Druid. The lodes wrought by these mines belong to the same series as those worked in Cook's Kitchen, Dolcoath, and Camborne Vean. It is almost impossible to give a complete account of the relations of the various lodes and their branches; and the available data are not easily reconcilable with one another.

The principal lodes can be identified in the mines situated along this series of lodes. The Barncoose lode in Carn Brea Mine is known in Tincroft Mine and Cook's Kitchen as the North Tincroft or East Pool lode,

* Phillips and Darlington. "Records of Mining and Metallurgy," 1857.

† "On the Discovery of Silver in the Mines of Cornwall." *Tr. R.G.S. Corn.*, vol. i., 1818, p. 123.

and in Dolcoath as the North Entral lode. The Highburrow lode in Carn Brea and Cook's Kitchen is known as the main lode in Dolcoath. Chapple's lode of Tincroft and Cook's Kitchen is recognised in Dolcoath as Harriett's lode. Teague's lode in Carn Brea is the same as Dunkin's lode in Tincroft and Cook's Kitchen and Richards' lode in Dolcoath. The South lode of Cook's Kitchen is known as the South lode in Dolcoath. The Druid South lode in Carn Brea Mine is the same as the Providence lode in Tincroft and Cook's Kitchen and the Brea lode of Dolcoath.

Druid Lode.—The underlie is from 15 deg. to 40 deg. north. The lode varies in width from 1 to 2 feet. In depth it is 4 feet wide. The eastern part of the lode is in killas and is split into two parts. Westwards, the lode is in granite and is split into three north-underlying branches. In the eastern part the lode was not of much value in the upper levels. In the granite the lode has a good gossan with clay and "prian." Black, grey, and yellow copper ores occurred in horizontal bunches from adit to the 36-fathom level. At the 112-fathom level there was both copper and tin ore, and from the 145 to the 204-fathom level the lode varied in width from 4 to 6 feet, and contained tin ore. On the whole there was not much copper below the 70-fathom level. The back (outcrop) of the lode was worked away in olden times.

Druid Caunter Lode.—Bearing E. 20 deg. S. Nearly vertical and varies in width from 1 to 3 feet. It runs into the Druid lode on the north side at about 30 fathoms east of Druid New shaft, and is 24 fathoms north of Vigur's lode. The copper ore in this lode extended for 80 fathoms in the direction of strike between adit and the 50-fathom level, but below the 60-fathom level it was poor and very quartzose.

Jenkins' Lode.—Underlie 10 deg. N. About 2 feet wide. It is situated 40 fathoms south of the Druid lode and is one of the most southerly lodes in the sett. In granite it is ferruginous and clayey.

Vigur's Lode.—A Caunter lode running into the Druid lode on the north side about 15 fathoms east of Druid New shaft. It is nearly vertical, and roughly parallel with the Druid Caunter. In width it is about 3 feet. Vigur's lode has a good gossan and was rich in copper ore in the upper levels. At the 105-fathom level it yielded a fair amount of tin ore.

Druid North Lode.—Much the same bearing as the Druid lode. Underlie is slightly north and it drops into Teague's lode below the 200-fathom level. Yielded tin ore.

Teague's Lode.—Underlie at Old Engine shaft is 13 deg. south. At Barker's shaft the underlie to the 50-fathom level is 15 deg. south. From the 50 to the 80-fathom level the underlie is 10 deg. north. From the 80 to the 150-fathom level the underlie is 10 deg. south. The changes in underlie did not affect its productiveness. It is from 2 to 7 feet in width, and converges with the Highburrow lode in depth. At the 141-fathom level it is 20 feet in width.* The veinstone is "priany," quartzose and ferruginous. From the 34 to the 105-fathom level for 100 fathoms in direction of strike the lode yielded good copper ore; and from the 80 to the 135-fathom level some tin ore. Known as Dunkin's lode in Tincroft Mine.

Dobree's Lode.—It is a branch of Teague's lode on the south side. It underlies north from 18 deg. to 30 deg. The lode contained copper ores from the 20 to the 70-fathom level for 80 fathoms in direction of strike.

North or Dawe's Lodes.—Branches of Teague's lode on the north side. Underlie from 27 deg. to 40 deg. They yielded copper ore from the 34 to 105-fathom level for about 50 fathoms in direction of strike, but they became unproductive at a distance from Teague's lode. From 2 to 6 feet in width.

Hichen's Lode.—Underlie north 20 deg. to 40 deg. Width from a few inches to 1½ feet. Yielded copper ore from 34 to 70-fathom level but was poor below.

Highburrow Lode.—Bearing E. 30 deg. N. In the upper levels it is nearly vertical but gradually underlies south. The width varies from 2 to 12 feet. The main part of the lode is in the western part of the sett.

* Henwood.

From the 60 to the 105-fathom level large quantities of tin ore were extracted for a distance of 150 fathoms in direction of strike. At the 200-fathom level there was both copper and tin ore. At the 250-fathom level it was very rich in tin ore, but at the 310-fathom level the lode was wrung up in an elvan and became valueless. Phillips states that about the 100-fathom level the lode yielded both tin and copper "either mixed or running down the lode side by side."*

Barncoose Lode.—This lode runs into the Barncoose Mine. The lode is about 3 feet wide. It is very quartzose and yielded tin ore at adit level. At the 100-fathom level the lode is 4 to 10 feet in width. At the 136-fathom level the lode yielded rich tin ore. Further west in Tincroft Mine the lode is known as the North Tincroft lode. In this part of the mine wolfram and tin ore occur. It is possibly this lode to which Carne refers when he states that wolfram and uranium oxide were found in an "east and west copper lode."†

There are a number of other lodes which have received notice from Thomas and Henwood; but some of them cannot now be identified.

All the lodes in the upper parts contained copper pyrites and vitreous copper ore. Native copper‡ as well as purple and indigo§ copper ores occurred. A mineral called condurrite (pitch copper) was found in the east part of Carn Brea Mine (Wheal Druid), within 10 fathoms of a cross-course. The lode yielded condurrite for a width of 3 to 4 feet, with a vein in the middle of native copper from ⅛ inch to 2 inches wide. The lode was soft and reddish, and the condurrite was taken from it in small nodules. The rest of the lode is iron oxide, quartz, chlorite; with a little tin ore and mispickel.‖

In Wheal Druid the lodes contained specular iron, arseniate of iron, wolfram, and tin pyrites, in addition to tin ore.¶

Chrysocolla occurred in Carn Brea, and small veins of cuprite 2 mm. in width. The felspar crystals of the granite in which they occur are partly converted to chrysocolla.**

The mine was first worked on a large scale in 1830.††

Between the years 1830 and 1856 the mine sold by public ticketing 161,593 tons of copper ore yielding 12,039 tons of copper.‡‡

In Carn Brea Mine the average yield of "black tin" from 1872 to 1881 was 35 lbs. per ton. In Tincroft during the same period the yield was 53 lbs. per ton.§§ The mining cost per ton during the same period was 14s. 3d. The cost of dressing was 3s. 9d. Mr. Collins states that there was a poor zone in the main lode near the 238-fathom level.‖‖

Henwood states that in sinking on Dunkin's lode, in the Tincroft part of the Carn Brea Mines, the first 26 fathoms was in granite. Below this to 84 fathoms below surface the lode is enclosed by killas; and below this again is the main mass of granite.

Near Martin's lode there are several irregular patches of granite, all heaved by the eastern cross-course. There is a third mass of granite extending from the main mass to within 25 fathoms of the surface. No granite veins have been encountered north of these places.¶¶

* "On the Veins of Cornwall." *Tr. Geol. Soc.*, 1814, vol. ii., p. 154.

† J. Carne, "On the Veins of Cornwall." *Tr. R.G.S. Corn.*, 1822, vol. ii., p. 61.

‡ Henwood, p. 65.

§ J. Garby. *Tr. R.G.S., Corn.* vol. vii., 1847, p. 85.

‖ J. Garby. *Op. cit.*, vol. vi., 1846, p. 194.

¶ *Op. cit.*, p. 83.

** W. Semmons. *Min. Mag.*, vol. ii., 1878, p. 200.

†† J. Maynard, "Remarks on Two Cross Sections," &c. *Rep. Roy. Corn. Poly. Soc.*, 1871, p. 193.

‡‡ Phillips and Darlington, "Records of Mining," p. 857.

§§ R. J. Frecheville, "Notes on the Great Main Lode of Dolcoath," &c. vol. x., 1879 to 1887. *Tr. R.G.S. Corn.*, p. 147.

‖‖ J. H. Collins, "Origin and Development of Ore Deposits, &c." *Journ. Roy. Inst. Corn.*, 1892, p. 75.

¶¶ Henwood pp. 60, 198.

Cook's Kitchen Mine.—Maynard in 1874 states that the mine had worked continuously for 130 years,* and that the lodes yielded copper ore to the 111-fathom level, below which they have yielded mainly tin ore. In 1814 this mine was one of the most productive tin mines in Cornwall.† The average yield of black tin per ton of ore from 1872 to 1881 was 43 lbs. The cost of mining for the same period was about 16s. 4½d. per ton, while the cost of dressing was 4s. 5½d. Between 1815 and 1856, 43,606 tons of ore were sold by public ticketing, yielding 1,484 tons of copper.‡ The mine has been worked to a depth of at least 430 fathoms below adit.

Chapple's Lode.—The underlie is south 15 deg. to 20 deg. Eastwards it drops into the Highburrow lode, which is the main lode of Carn Brea and Tincroft. The lode has yielded immense quantities of copper pyrites and rich grey copper ore and tin, and especially at the junctions with its numerous branches. The ore shoots follow the lines of intersection of lodes and pitch eastwards.§

In width it varies from 6 to 20 feet. At the 332 and 345-fathom levels, just below the point where Dunkin's lode drops into Chapple's, the lode varies in width from 15 to 20 feet.‖

At the 400-fathom level it is 30 feet wide. The lode yielded a great deal of copper ore from the 16-fathom level to below the 100-fathom level; grey copper and copper pyrites mixed with "peach," "prian," and capel occurred down to the 160-fathom level. The greatest wealth began below the 200-fathom level, the lode varying in width from 5 to 8 feet, and contained good tin ore down to the 400-fathom level (below the junction of Dunkin's and South lode). Here the lode is 30 feet wide and consists of peach and capel with 4 feet of chlorite and flucan, which contained about 40 lbs. of black tin per ton of stuff for a distance of over 60 fathoms in the direction of strike. At the 320-fathom level the lode was divided into two parts (by a smooth wall) the total width of which is 12 feet. The south part (or hanging wall) consisted of peach and tin ore; while the north part (or the foot wall) yielded copper ore. Chalybite is common in the lode.

Dunkin's Lode.—This lode had a fair gossan and yielded copper ore from the 30 to the 100-fathom level, in killas and granite alike. The veinstone was mainly a ferruginous chloritic mass of crushed quartz. From the 170-fathom level where a little copper was found down to the 222-fathom level the lode yielded tin ore. It varied in width from 2½ to 8 feet. The lode contained quartz, fluorspar, carbonate and oxides of iron, cupreous and arsenical pyrites, and tin ore. In the upper levels it varies from 1 to 12 feet in width.

At the 48-fathom level in Dunkin's lode the north wall is granite, and the south wall is slate traversed by several granite veins. At the 52, 55, and 68-fathom levels the north (or foot) wall is slate and the south wall granite. At the 73-fathom level the south wall is slate and the opposite wall granite.

Eddy's or Eudey's Lode.—This lode yielded copper pyrites down to the 100-fathom level, while below that, at the 121-fathom level, good tin ore was found.

Richard Thomas (1819) gives a brief account of the lodes being worked in his time, but some of the names he gives to the lodes have long since been forgotten, or the lodes have been renamed.

The lodes yielded copper ore down to the 150-fathom level. Pryce states that several tons of native copper were sold from Cook's Kitchen Mine.¶ Vitreous and other copper ores occurred in abundance. The occurrence of

* J. Maynard, "Mines of the Illogan District." *Rep. Corn. Poly. Soc.*, 1874, p. 86.

† Daniel and Samuel Lysons. *Mag. Britt. Corn.*, vol. iii., 1814, p. 206.

‡ Phillips and Darlington, "Records of Mining and Metallurgy."

§ R. J. Frecheville, "Notes on the Great Main Lode of Dolcoath," *Tr. R.G.S. Corn.*, 1879 to 1887, vol. x., p. 149.

‖ *Op. cit.* ¶ *Min. Cornub.*, 1778, p. 61.

mineral pitch has already been referred to elsewhere. The average yield of black tin from 1872 to 1881 was 43 lbs. to the ton.

It is in this mine that alternations of granite and killas were encountered in sinking on the lodes. Henwood* gives the following particulars :—At the 54-fathom level in the South lode, granite occurs in the south wall, and slate in the north. In Toys lode at the 54-fathom level the foot wall is granite while the horse of ground between two branches is partly granite and partly killas.

Middle Engine Lode.—At the 33-fathom level the north wall is slate and the foot wall granite, but at the 73-fathom level both sides are granite. At the 54-fathom level the north wall of the Hard shaft is slate and the south wall granite.

The Crofty Mines.—The largest mine in the Crofty group is South Wheal Crofty, which formerly was divided into several properties of which North Crofty (or East Seton), South Crofty, East Crofty, and the Old Pool Mine were the principal. The area was divided into three sections. The western section was known as Longclose ; the middle section as Dudnance ; and the eastern section as Penhellick.

Fane's Lode (in Longclose section of the mine), bearing E. 8 deg. N.† The underlie is north from 14 deg. to 20 deg. Varies in width from 2 to 3 feet. The lode joins Reeves' lode as it runs westwards, and although extensively explored, is comparatively poor. It has yielded a little copper pyrites, and at the 71-fathom level it is in greenstone and is of a quartzose nature.

Another lode 25 fathoms north of Fane's, contained copper but was valueless in depth. In width this lode was about a foot. The underlie is 10 deg. N. Another lode called the *Red Lode* is situated (at the 80-fathom level) 40 fathoms north of Fane's lode. It is 1 foot wide, has a southerly underlie and consists of quartz and peach.

Reeves' Lode.—Bearing E. 3 deg. S.‡ Underlie 15 deg. N. It is a large well-defined lode which yielded copper ores from 20 to the 100-fathom levels. The lode has a splendid gossan, and copper ore occurred to the 90-fathom level for a distance of 350 fathoms in the direction of strike. It joins the Trevenson lode in depth. Henwood states that the lode varies in width from 1 to 6 feet and contained in addition to copper ore—iron pyrites, blende, mineral pitch, earthy brown iron ores, chlorite, and fluorspar to a depth of 125 fathoms below adit. It also yielded tin ore, and at the 205-fathom level the lode intersected an elvan and was richer in tin ore below the elvan than above it. It was very rich in copper in the Old Pool Mine, and was productive also in Wheal Crofty (now part of North Roskear sett)§ where it is known as the Great Caunter, and it passes into Wheal Seton where it is the main lode.

Trevenson Lode.—Situated south of Reeves' lode. Henwood states that the bearing is E. 2 deg. S. Underlie is from 14 deg. to 40 deg. north. In width it varies from 1 to 3 feet. The lode yielded some copper ore but was poor below the 110-fathom level.

Cherry Garden Lode.—Situated south of Trevenson lode. Underlie is 10 deg. to 15 deg. north, to a southerly direction. The lode varied in width from 1 to 4 feet. Henwood states that the lode contained copper and iron pyrites and blende to the 88-fathom level. Maynard states that the lode yielded good copper ore at shallow levels ; below the 110-fathom level there was no copper in the lode, but there was a little tin ore.‖

Longclose Lode.—Situated south of Cherry Garden lode. The lode is nearly perpendicular from surface to the 35-fathom level, but is not so steep in depth ; the underlie varies from 8 deg. to 20 deg. north. The lode has a fine gossan and it yielded copper ore from adit to the 35-fathom level for 100 fathoms in direction of strike. Below this down to the 115-fathom level the lode was not of great value. The lode also contained

* p. 198.
† H. C. Salmon. *Min. and Smelt. Mag.*, vol. ii., 1862, p. 17.
‡ *Op. cit.*, p. 74. § *Op. cit.*
‖ "Mines of the Illogan District." *Rep. Corn. Poly. Soc.*, 1874, p. 86.

blende and fluorspar. At the 126-fathom level it is 1 foot wide and still in killas.

South Lode.—South of Longclose lode. Underlie south 10 deg. and varies in width from 1 to 6 feet. Yielded copper ores to the 70-fathom level. Bearing approximately E. and W.

Longclose Caunter Lode.—Situated on the south of Longclose lode. Bearing E. 30 deg. S. (Henwood). Nearly vertical to the 35-fathom level after which it underlies N. 13 deg. It varies in width from 1 to 3 feet. The lode branched off from the Cherry Garden lode near the Engine shaft, and yielded copper ores down to the 125-fathom level. Blende, iron pyrites, fluorspar, and quartz were also present in the lode.

Penhellick Lode.—Situated in the south-east part of the sett. Bearing approximately east and west. It underlies south at a varying angle. In width it is from 1 to 6 feet. There is a good gossan; and from the adit level to the 50-fathom level copper ore occurred for 100 fathoms in direction of strike. At the 100-fathom level it still yielded copper ore; at the 110-fathom level it was very watery.

Copper Tankard Lode.—This is a Caunter lode situated in the south-west corner of the sett. The bearing is about E. 20 deg. or 30 deg. S. At adit level the lode is 6 feet wide, and contains quartz, iron pyrites, zinc-blende, and copper ore, near an elvan. At the 24-fathom level the lode is 1 foot wide in places, and the bunches of ore of no great extent. At the 70-fathom level the lode is 3 feet 6 inches wide but valueless. The country rock at this level is diabase.

Dudnance.—A lode explored at the 16-fathom level is 1 foot wide.

Wheal Knight Lode.—In the western end of the sett. Bearing E. 33 deg. N. Underlie north 16 deg. to south 10 deg. In the Wheal Crofty part of the sett there are several lodes the particulars of which have been given by Henwood. Most of the lodes contained iron and copper pyrites and other copper ores. Blende and galena were also found in some quantity. At the present time only the central and eastern part of the South Crofty sett is being worked. The lower part of the mine is well within the granite and extends below the 260-fathom level. The mine yields tin ore and a little wolfram.

The North Lode underlies south at about 30 deg. at the 225-fathom level, and forms a junction with the middle lode below the 260-fathom level. The lode varies in width up to about 7 feet and yields good tin ore.

Pryce's Lode.—The bearing is about E. 15 deg. N. In the upper levels the lode is nearly vertical, but its average underlie in the lower levels is about 20 deg. south. At the 205-fathom level it joins the South lode. (It forms a junction also with Palmer's lode at about 80 fathoms west of the Engine shaft. This lode underlies south about 10 deg.) At the 112-fathom level the lode is from 8 inches to 8 feet in width near Palmer's shaft. At the 260-fathom level the lode is from 3 to 5 feet in width. Pryce's lode has yielded mainly copper ores down to the 100-fathom level. Below this in the granite the lode yields mainly tin ore. At the 112-fathom level the lode divided into two parts. The north part at the 260-fathom level is 3 to 5 feet in width. The lode consists of blue capel and peach, quartz, chlorite, and fluorspar. Some of the cross-courses intersecting the lode contain quartz made up of zoned crystals.

The Middle Lode is situated between Pryce's lode and the North lode. It branches off from the north side of Pryce's lode below the 100-fathom level, and joins the North lode below the 260-fathom level. It varies in underlie but is nearly vertical. Not a very rich lode.

The South Lode is situated south of Pryce's lode and underlies north, joining the latter at the 205-fathom level.

East Wheal Crofty sold by public ticketing, between the years 1832 and 1854, 100,952 tons of copper ore containing 7,280 tons of metallic copper. South Wheal Crofty between 1854 and 1856 yielded 2,209 tons of ore containing 104 tons of copper. North Wheal Crofty in the same time yielded 3,713 tons of ore containing 233 tons of copper.*

* Phillips and Darlington. "Records of Mining and Metallurgy," 1857.

Dolcoath Mine.—Much of the following information has been extracted from the unpublished annual reports of the mine, while the rest of the detail was obtained by personal inspection rendered possible by the courtesy of the mine manager, Mr. Arthur Thomas, and the generous assistance of the staff. The workings of the Dolcoath main lode extend to a greater depth than those of any other tin mine in the world. The deepest workings are in the eastern part of the mine, and reach 3,120 feet from surface, or about 2,940 feet below adit, the distance being measured along the underlie of the lode. The mine has held a prominent position in the mining world ever since the introduction of the pumping engine in the eighteenth century, and is mentioned by Pryce and other early writers. In the old days the Dolcoath Mine formed only part of the present property, which comprises the old mines of Wheal Harriet, Dunkin's Garden, Stray Park, Wheal Gons, Dolcoath, &c. The details of the mineral output of the mine prior to 1815 are practically unprocurable, as the information is either altogether lacking or is scattered through the pages of weekly papers published about the beginning of the nineteenth century. The total yield of metallic copper from this mine between the years 1815 and 1836, in 1838, and between 1845 and 1903, was 16,100 tons. Phillips and Darlington state that for all the years between 1815 and 1856, 241,522 tons of ore were sold by public ticketing containing 17,478 tons of metallic copper. In 1841, copper ore, sold at £5 a ton, realised £18,529. The total output of black tin is 77,500 tons between the years 1853 and 1905.

The Main Lode has been worked westwards in Camborne Vean Mine, and eastwards in Cook's Kitchen, where it is called Chapple's lode, and in Tincroft and Carn Brea, where it is known as the Highburrow lode.*

There are at least three elvans in the sett† which underlie north, but the most southerly of them probably underlies south in depth.

There are over a dozen ore-bearing fissures, each of which has received a distinctive name by the miners.

The main lode in the eastern part of the mine is in killas to the 80-fathom level (adit about 30 fathoms below surface). In the western part of the mine it does not reach the granite until a depth of 230 fathoms is reached. From surface to about the 80-fathom level the lode is vertical; thence to the 125-fathom level it is 6 or 7 deg. south underlie. From the 125 to the 216 it is about 15 deg. south; and at the bottom of the mine, near the 485-fathom level, it underlies south at 44 deg. In the eastern part of the mine, near its junction with the South Entral lode, it is 60 feet wide, but in descending it thins off to about 3 feet at the 145-fathom level. Near the surface the lode is 3 to 6 feet wide. From the 150-fathom level to the 200-fathom level near the Engine shaft the width is from 7 to 12 feet. From the 200 to the 338-fathom level it varies in width from 1 to 9 feet.

The lode had a very fine gossan containing a little tin ore, and was exceedingly rich in copper ore down to the 150-fathom level and a little below. From this to the 190-fathom level there was both copper and tin ore, and Mr. Collins states that between the 170 and the 190-fathom levels there was a poor zone in the lode which at the time it was encountered discouraged the adventurers.‡ Below the 190-fathom level no copper has been found in any quantity.

In the eastern part of the mine where it encountered the South Entral lode (and was so wide) there was a good deal of quartz and fluorspar. The north or main part of the main lode, at the 180-fathom level, also contained fluorspar, while the remainder of the lode was chlorite and peach. At the 338-fathom level rich ground worth over £105 per cubic fathom for

* R. J. Frecheville, "Notes on the Great Main Lode of Dolcoath." *Tr. R.G.S. Corn.*, 1879–87, vol. x., p. 146.

† De la Beche, p. 176.

‡ J. H. Collins, "Origin and Development of Ore Deposits." *Journ. R. Inst. Corn.*, 1892, p. 75.

tin ore was encountered. At the 364-fathom level, near the Engine shaft, the lodestuff yielded 10 per cent. of tin ore in some parts of the lode which is here 20 feet wide.*

South Branch.—This lode breaks off from the main lode towards the south at about the 60-fathom level, but curving round it drops into the main lode again at the 125-fathom level. It was never an important lode, but contained copper ore from the 70-fathom level to the 120-fathom level for a distance of 60 fathoms in direction of strike.

Harriett's Lode.—In the upper levels it has a bearing of about E. 20 deg. N., but from the 70-fathom level to the 180-fathom level it gradually changes its strike until its bearing is E. 40 deg. N., and in the eastern part of the mine joins the main lode at a place where large quantities of copper ore were obtained. Where it changed its strike from E. 20 deg. N. to E. 40 deg. N., it was poor. At a point a little below where Harriett's lode joins the main lode there is a branch from the north side of the main lode which is considered to be a continuation of Harriett's lode, and to be the same as is known in Cook's Kitchen Mine as Eddey's lode. Harriett's lode had a poor gossan, and yielded no copper ore until opened up at the 110-fathom level, after which it produced copper ore down to the 180-fathom level, especially eastwards, and a few bunches of tin ore near the main lode.

South Lode.—This is an important branch of the main lode and has a general strike of about E. 30 deg. N. It is very nearly vertical to the 190-fathom level, after which it underlies S. 15 deg. to about the 290-fathom level, and, after underlying a little more, it drops into the main lode at the 375-fathom level. It varies in width from 6 inches to 2 feet in the upper levels, but is much wider and more productive in depth, and was extremely rich in tin ore near the junction with the main lode. In the upper levels it has a peach and quartz veinstone.

Richard's Lode.—This is situated between the South and Harriett's lodes. Its strike is about the same as that of the main lode. Starting from surface it underlies northwards at 13 deg., but in depth it reverses its underlie and drops into the South lode near the 242-fathom level. Westwards it forms a junction with Harriett's and the main lode. It has an average width of 2 feet, and contained a little copper ore from the 100 to the 140-fathom levels.

North (or Valley) Caunter.—The main lode branches at the Gossan shaft, near the eastern boundary of the sett. One part runs northwards and is known as the Valley Caunter. At the point where it branches from the main lode it has a bearing E. 60 deg. N., but meeting with the South Entral lode and Silver lode (situated on the north of the main lode) its bearing became E. 30 deg. N. The underlie is 5 deg. S. Before it encounters the South Entral lode it varies in width from 6 to 10 feet, but at its junction with this lode it is from 20 to 60 feet in width. It contained immense quantities of copper ore from the 20 to the 130-fathom level, but was very poor below. It was very hard near the Great cross-course.

The Valley Lode.—Situated to the south of the main lode east of the Gossan shaft. The bearing is similar to that of the main lode, but as it approaches the eastern boundary of the sett it turns more northwards. In depth it is this part of the mine which is now principally worked. It has always been a good lode.

South Entral Lode.—Situated on the north of the main lode, and has a bearing of about the same amount, but it varies slightly in the eastern and western parts of the mine. The underlie is about 13 deg. S. It varies in width from 1 to 3 feet. The walls in some places are sharply defined, and occasionally in the killas the capel is still to be seen. There was a fair gossan, and the lode was productive in copper ore from adit to the 50-fathom level for a distance along the strike of 160 fathoms.

* R. J. Frecheville, "Notes on the Great Main Lode of Dolcoath." *Tr. R.G.S. Corn.*, 1879-87, vol. x., p. 149.

Silver Lode.—Situated on the north of the South Entral lode. Bearing E. 30 deg. N. Its underlie is 13 deg. N. In width about 2 feet. About £3,000 worth of silver ore was obtained from this lode between deep adit level and 15 fathoms from surface. Eastwards and in depth it was unproductive.* The silver was vitreous and ruby ore. The lode contained a good deal of flucan (clay).

North Entral Lode.—Situated to the north of the Silver lode. Bearing E. 30 deg. N. Underlie 27 deg. to 30 deg. N., and is about 4 feet wide. Another lode on the north of this is 1 to 3 feet in width, underlies south at 30 deg., and intersects it. It had only a moderate gossan, and yielded copper ore about adit level. At the 42-fathom level there was mundic.

The Caunter Lode.—This lode breaks off from the Dolcoath main lode on the south side at Wheal Bryant shaft. Bearing E. 4 deg. S. Underlie is 15 deg. S., but it is steeper in depth. In width it varies from 6 inches to 1 foot. The lode encounters the South lode at about 50 fathoms west of Bryant shaft. It had fine bunches of gossan to within 20 fathoms from surface, and was very rich in copper from adit level to the 80-fathom level for 150 fathoms east of its junction with the main lode. The veinstone is quartzose and chloritic. It was recently intersected by the 220-fathom level cross-cut, which was driven south from the main lode, and at that depth it contained a little cassiterite. At the 70-fathom level there are a few branches from the Caunter lode.

The main lode has several small branches which are of insignificant importance. One is named *Rule's Lode*, which branches off at the 70-fathom level. It contained copper ore from the 70 to the 100-fathom level for a distance of 60 fathoms along its strike. The other is called the *Culvert course*, which branches off from the main lode at the 50-fathom level, and contained copper from the 50 to the 80-fathom level. Another lode of small importance, known as *Martin's Lode*, starts from surface between the main and South Entral lodes. It underlies north and intersects the South Entral at the 40-fathom level. This lode had very little gossan but contained copper near the Great cross-course.

The Brea or Plantation Lode.—This is the most southerly lode in the sett. It is nearly vertical, and was recently intersected by the William's New shaft, which was sunk vertically to meet the 220 cross-cut. The lode contains cassiterite, mispickel, and chloritic materials. The strike is E. 30 deg. N., and in width it is about 1½ feet.

Generol Remarks on Dolcoath Mine.—In addition to the ores of tin, copper, and silver, there occurred bismuth, arsenic, cobalt, and pitchblende. Thus, arseniate of cobalt was found in one of the lodes containing copper,† and in some places in the main lode it was intimately mixed with tin ore to the extent of about ½ per cent.‡ Native bismuth and bismuth sulphide with pitchblende, arsenical cobalt, quartz, and fluorspar also occurred.§ (See also Index of Minerals, p. 195.)

The character of the veinstones has been described by several writers. Henwood states that in granite the lode is brecciated.‖ Mr. Collins examined some of the ores with the microscope. A specimen of veinstone from the 314-fathom level shows veins of quartz cutting through an "acicular mass of blue tourmaline, and are themselves traversed by veins of cassiterite." Another stone "is evidently a breccia; it consists of angular patches of fine-grained green or bluish green material, which is apparently composed in the main of a network of fine needles, embedded in a crystalline

* Information obtained from unpublished Mine Records. De la Beche states that £2,000 worth of silver ore was obtained, p. 288.

† J. Carne, "On the Veins of Cornwall." *Tr. R.G.S. Corn.*, 1822, vol. ii., p. 105.

‡ R. Pearce, "Note on the Occurrence of Cobalt in connection with the Tin Ores of Cornwall." *Journ. Roy. Inst. Corn.*, vol. iv., 1872, p. 81. See also Josiah Thomas, *op. cit.*, vol. iii., 1868, p. 142.

§ R. Pearce, "Note on Pitchblende in Cornwall." *Tr. R.G.S. Corn.*, 1864 to 1878, vol. ix., p. 103.

‖ p. 212.

mass of cassiterite, which exhibits distinct crystals in a few places. A little quartz occupies the interspaces which are few—and this encloses many fine needles of tourmaline." Another stone from the 260-fathom level contains 60 per cent. of tin. It "is a mass of rather large grey crystals." "With the cassiterite is a little quartz and some fringed crystals of tourmaline. Some of the crystals contain embedded needles which are probably schorl."* Dr. Flett has also described some of the Dolcoath veinstones. (See p. 138.) Killas obtained from the 215-fathom level has been microscopically described by Phillips. It is "exceedingly hard with an imperfect cleavage, and is of a dark grey colour. Under the low power (400 diam.) small grains of magnetite are distinguished from which as a centre indistinct fan-like aggregations of perhaps some variety of chlorite diverge in all directions." "It also contains broken and rounded plates of mica and a few fragments of brown semi-transparent mineral, mechanically embedded in slate."† A large mass of slaty rock was encountered in the main lode on the east of the Eastern shaft at the 352-fathom level. At this place the main lode is well within the granite and about 240 fathoms below the junction of the granite and killas.‡ A piece of striped hornfels was recently discovered in the lode at the 375-fathom level, near Stray Park shaft, at which point the lode is in granite.

Elvans are seen at the 375-fathom level in Stray Park ; in the 220 cross-cut between Sump shaft and William's New shaft underlying north a few degrees ; at the 220-fathom level at Sump shaft between Richard's and the main lode ; also at 375, 388, 400, and 412-fathom levels near the Old Sump shaft in the vicinity of the main lode. At the 400-fathom level near Old Sump shaft an elvan underlies in a north-easterly direction 55 deg. ; at 266-fathom level there is an elvan below Harriett's lode. At 352-fathom level on south of South lode, at 100 and 160 fathoms east of the Engine shaft, an elvan is seen underlying south in the same direction as the lode which is situated on its foot wall. An elvan is seen at the 254-fathom plat at Valley (or Eastern) shaft and is again seen in a cross-cut on the west of the shaft. Another in the same cross-cut is again seen at the 302-fathom level between the main and South lode. An elvan crops out at the margin of the granite and underlies N. 45 deg., but becomes perpendicular and then south underlying in the granite. An elvan on the north of the Engine shaft underlies N. 40 deg. ; another cropping out about 170 fathoms north of the engine shaft underlies N. 40 deg.

Dolcoath Mine has been worked for well over a century and a half. Josiah Thomas states that the depth of the mine in 1758 was 88 fathoms. In 1788 it was 183 fathoms. In 1824, 240 fathoms, and in 1868, 340 fathoms.§ At the present time the deepest workings are 490 fathoms below adit level.

The cost of driving an end 8 feet high and 6 feet wide was, in 1868, about £20 a fathom in hard ground. The cost of breaking the ore and sending it to surface is about 5s. 6d. per ton.‖

The average yield of black tin per ton from 1872 to 1881 was 59 lbs., while during the same period the cost of mining was 16s. 11d. per ton, and of dressing 3s. 10½d. per ton.¶

The following notes are extracted from the Report of the Directors issued in June, 1906, to the shareholders in the mine :—

The profits earned in the half-year (January to June, 1906) amount to £40,165.

The following table shows the progress of the present company's operations since its commencement :—

* J. H. Collins, "Cornish Tinstones and Tin Capels." *Min. Mag.*, 1882, vol. iv., p. 11.

† J. A. Phillips. *Q.J.G.S.*, 1875, vol. xxxi., p. 323.

‡ J. A. Phillips, "Ore Deposits," 2nd edition, p. 213.

§ Josiah Thomas. *Journ. Roy. Inst. Cornwall*, vol. iii., 1868, p. 192.

‖ *Op. cit.*

¶ R. J. Frecheville, "Notes on the Great Main Lode of Dolcoath." *Tr. R. G.S. Corn.*, vol. x., p. 147.

Six Months ending.	Tin Ore crushed.	Black Tin sold.				Produce per ton of Ore.	Average price per ton of Ore.			Average price per ton of Black Tin.			Amount realised.		
	Tons.	Tons.	c.	q.	lbs.	lbs.	£	s.	d.	£	s.	d.	£	s.	d.
Dec. 31st, 1895	28,717	1,015	5	1	16	79·19	1	7	8·36	39	3	5	36,769	2	5
June 30th, 1896	30,015	1,029	19	1	10	76·86	1	5	6·33	37	4	0	38,311	6	5
Dec. 31st, 1896	33,712	1,009	7	0	25	67·06	1	1	10·2	36	9	2	36,830	18	2
June 30th, 1897	35,879	1,021	17	0	22	63·79	1	1	7·27	37	18	7	38,760	7	2
Dec. 31st, 1897	37,686	1,073	2	1	9	63·78	1	1	6·78	37	17	4	40,636	19	8
June 30th, 1898	38,089	1,140	7	2	22	67·07	1	3	8·94	39	16	4	45,221	15	1
Dec. 31st, 1898	40,608	1,162	0	0	0	64·10	1	6	10·09	46	18	0	54,497	6	3
June 30th, 1899	41,101	1,037	19	1	23	56·57	1	13	8·21	66	12	7	69,222	12	8
Dec. 31st, 1899	41,639	1,040	18	1	19	56·00	1	19	8·39	79	7	11	82,651	16	0
June 30th, 1900	45,102	1,043	9	0	0	51·80	1	18	3·57	82	15	4	83,364	18	10
Dec. 31st, 1900	43,254	960	19	1	21	49·76	1	15	11·4	80	18	2	77,750	14	4
June 30th, 1901	47,603	1,001	18	1	5	47·14	1	10	8·69	72	19	10	73,132	0	11
Dec. 31st, 1901	48,975	1,033	13	1	18	47·28	1	8	10·35	68	7	6	70,676	2	6
June 30th, 1902	48,155	934	15	2	21	43·48	1	7	10·76	71	17	1	67,168	6	6
Dec. 31st, 1902	52,295	893	13	2	19	38·28	1	4	9	72	8	4	64,716	7	4
June 30th, 1903	47,899	863	14	3	13	40·39	1	8	11	80	3	6	69,251	5	0
Dec. 31st, 1903	51,011	876	2	2	12	38·47	1	5	2·08	73	5	8	64,206	15	6
June 30th, 1904	50,196	810	15	0	23	36·18	1	4	1·28	74	12	6	60,504	10	2
Dec. 31st, 1904	50,353	894	8	3	0	39·79	1	7	5·42	77	5	5	69,114	16	4
June 30th, 1905	49,974	829	18	2	23	37·20	1	6	11·26	81	2	1	67,311	16	11
Dec. 31st, 1905	48,472	866	18	3	21	40·06	1	12	0·46	91	17	11	79,669	13	1
June 30th, 1906	49,934	920	4	3	20	41·28	1	18	11·5	105	13	4	97,268	0	9

The Receipts, Expenditure, and Profits for 17 half-years on Profit and Loss Account were as follows :—

——	Receipts.			Working Cost.			Gross Profits.			Lord's Royalties.			Net Company's Profits.		
	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.
First Half of 1898	46,007	17	8	37,019	18	6	8,987	19	2	1,721	18	3	7,266	0	11
Latter „ of 1898	55,284	13	2	38,862	7	1	16,422	6	1	2,270	14	5	14,151	11	8
First „ of 1899	69,983	13	10	42,910	16	8	27,072	17	2	4,614	16	10	22,458	0	4
Latter „ of 1899	83,492	15	11	46,915	3	1	36,577	12	10	5,511	7	5	31,066	5	5
First „ of 1900	87,038	12	2	48,866	8	7	38,172	3	7	5,757	16	0	32,414	7	7
Latter „ of 1900	78,626	3	5	50,898	11	10	27,727	11	7	5,183	7	7	22,544	4	0
First „ of 1901	73,727	1	10	51,949	3	10	21,777	18	0	4,875	9	4	16,902	8	8
Latter „ of 1901	71,723	2	5	50,737	8	11	20,985	13	0	4,711	14	10	16,273	18	8
First „ of 1902	67,926	8	10	49,054	17	9	18,871	11	1	4,477	17	9	14,393	13	4
Latter „ of 1902	65,281	17	1	48,928	12	1	16,353	5	0	4,314	8	5	12,038	16	7
First „ of 1903	69,762	11	3	49,031	8	3	20,731	3	0	4,616	15	0	16,114	8	0
Latter „ of 1903	64,812	18	9	49,528	10	6	15,284	8	3	3,280	9	0	12,003	19	3
First „ of 1904	61,143	3	5	50,182	14	4	10,960	9	1	2,951	0	5	8,009	8	8
Latter „ of 1904	69,699	4	4	53,674	13	9	16,024	10	7	2,303	16	6	13,720	14	1
First „ of 1905	67,934	0	8	53,350	0	4	14,584	0	4	2,243	14	6	12,340	5	10
Latter „ of 1905	79,733	5	4	54,691	17	7	25,041	7	9	2,655	13	1	22,385	14	8
First „ of 1906	97,910	18	0	54,502	18	9	43,407	19	3	3,242	5	4	40,165	13	11

Cost of Raising and Treating the Ore Per Ton.—

Six Months euding—	Receipts.	Charges.	
		Working Costs.	Lords' Royalties.
	£ s. d.	£ s. d.	£ s. d.
31st December, 1895	1 7 6	1 4 4	0 0 11
30th June 1896 -	1 5 10	1 3 1	0 0 10
31st December, 1896 -	1 2 6	1 0 10	0 0 9
30th June, 1897 - -	1 2 2	1 0 2½	0 0 8½
31st December, 1897	1 2 0	0 19 6	0 0 9
30th June, 1898 -	1 4 2	0 19 5	0 0 11
31st December, 1898	1 7 3	0 19 1	0 1 1½
30th June, 1899 - -	1 14 1	1 0 11	0 2 3
31st December, 1899 -	2 0 1	1 2 7	0 2 7
30th June, 1900 - -	1 18 7	1 1 8	0 2 6½
31st December, 1900	1 16 4	1 3 6	0 2 5
30th June, 1901 - -	1 10 11¾	1 1 9¾	0 2 0½
31st December, 1901	1 9 3½	1 0 8¾	0 1 11
30th June, 1902 - -	1 8 2¾	1 0 4½	0 1 10¼
31st December, 1902 -	1 4 11½	0 18 8½	0 1 7¾
30th June, 1903 - -	1 9 1½	1 0 5½	0 1 11
31st December, 1903 -	1 5 4¾	0 19 5	0 1 3¼
30th June, 1904 - -	1 4 4¼	0 19 11¾	0 1 2
31st December, 1904 -	1 7 8	1 1 3¾	0 0 10¾
30th June, 1905 - -	1 7 2¼	1 1 4	0 0 10¾
31st December, 1905 -	1 12 10¾	1 2 6¾	0 1 1¼
30th June, 1906 - -	1 19 2½	1 1 10	0 1 3½

East Pool and Wheal Agar United.—This sett is situated on the eastern extension of the same series of lodes which are worked in the adjacent mine of South Crofty. Borlase mentions the Old Pool Mine, and describes the mode of working the mine in his time.

The "backs" (outcrops) of the lodes in Wheal Agar were worked for tin by the "old men."†

The upper part of the mine is in killas to about the 135-fathom level; below this the lodes are in granite, and are being worked at the present time. The mine has yielded enormous quantities of both copper and tin ores, and in addition has proved to be an important repository of wolfram. Between 1847 and 1856, Wheal Agar sold by public ticketing 3,022 tons of ore yielding 390 tons of metallic copper; East Pool between 1835 and 1856 yielded 38,780 tons of ore containing 2,911 tons of metallic copper.‡

Main or Engine Lode.—The underlie to the 36-fathom level is 15 deg. S. At this level the lode is in contact with an elvan which underlies north, and below it to the 60-fathom level the lode is perpendicular. From the 60-fathom level downwards the underlie is about 15 deg. south. The lode had a good gossan and yielded copper ore in abundance. At the 150-fathom level the lode is 10 feet wide, and yielded both tin and copper ores. It was wrought for wolfram below the 135-fathom level.

* Borlase. *Nat. Hist. Corn.*, 1758, p. 167.

† J. Maynard, "Remarks on Two Cross Sections," &c. *Rep. Roy. Corn. Poly. Soc.*, 1871, p. 195.

‡ Phillips and Darlington. "Records of Mining and Metallurgy," 1857.

The Great Lode.—It is from this lode that most of the wolfram of the mine has been obtained. This lode was first encountered at about the 140-fathom level. It has been worked upon to below the 300-fathom level, and has yielded good tin and wolfram ore with mispickel, &c.

Pryce's Lode.—Situated on the north of the main lode and underlies north. It is the same lode that is being worked in South Crofty at the present time.

Middle Lode.—Situated north of the Great lode, and has a slight southerly underlie.

Palmer's Lode.—Vertical to the 50-fathom level, and then underlies south 13 deg. Varies from 1 to 3 feet in width. Near the western end of the sett, close to South Crofty, it forms a junction with the main lode at 50 fathoms west of Engine shaft. The veinstone consists of quartz and killas in the upper level, and the lode contained copper from the 26 to the 48-fathom level for 30 fathoms in direction of strike.

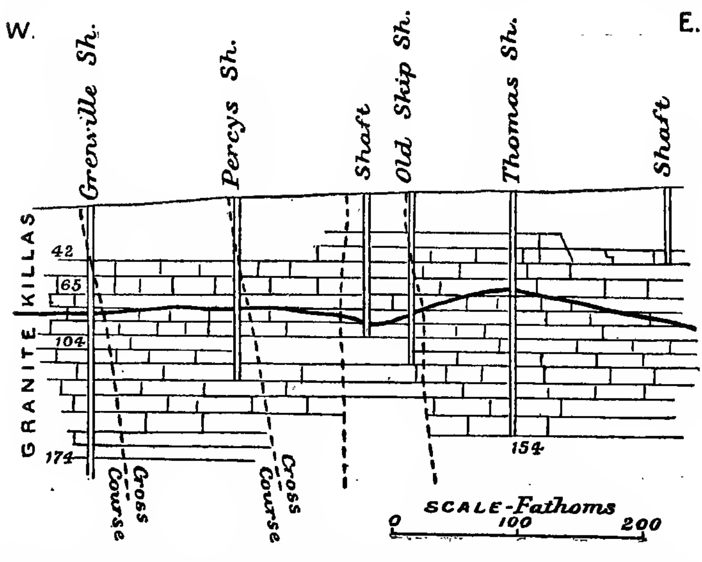
North (or Reeve's) Lode.—Underlies north 20 deg. Varies in width up to 2 feet, and contains quartz and copper pyrites.

South Lode.—Parallel with the main lode. Underlie N. 20 deg. At adit level the width is about 1 foot, but below the 70-fathom level it is 1½ to 4 feet wide, and at the 130-fathom level it is 7 feet wide in places. Near the western boundary, at the 100-fathom level, the lode is 30 feet wide. At adit level the lode consisted mainly of flucan (clay) and quartz. It yielded copper from the 40 to the 70-fathom level. From the 70 to the 100-fathom level there was both copper and tin. Copper ore was again abundant at the 130-fathom level, at which place the lode also contained tin, wolfram, and arsenic.

North Tincroft Lode.—Underlie N. 27 deg. At the 70-fathom level the lode is 1 foot wide and was poor.

West Basset.—The lodes of this mine have good gossans. When the mine was first opened up the copper lode was found to be very rich to

FIG. 22.—*West Basset North Lode. Longitudinal Section.*



below the 100-fathom level. The lodes on the south were not so rich, but yielded both tin and copper ores. The *Flat Lode* is heaved by the "*Old*

Lode" from the 134 to the 114-fathom level. Both the Caunter lode and the *New Lode* have yielded copper and tin.*

The Main or North Lode was not rich in copper ore eastwards (Fig. 22.)

Caunter Lode.—The ore bunches dip eastwards. The width of the lode at the 60-fathom level is 1½ feet, and it was a fairly good lode. Below the 114-fathom level it was 3 feet in width.

Middle Lode.—A good deal of tin ore was extracted from this lode near the place at which it cut the junction of the killas and granite.

The Great Flat Lode was intersected in depth while working on a north underlying copper lode. At the 140-fathom level the width of the capel and lode is 40 or 50 feet, and the whole is more or less tin bearing. The leader is frequently a mere ferruginous joint.† Between the years 1852 and 1856 the mine yielded 22,135 tons of ore containing 1,541 tons of copper.‡

THE ABANDONED MINES.

WHEAL ANN.—The Wheal Ann lode is the easterly prolongation of *Wheal Trumpet Lode.*—From the 122 to the 142-fathom level the lode has smooth walls and is enclosed in schorlaceous or decomposed granite. The lode yielded black tin ore associated with "brown iron ore."§

BALMYNHEER MINE.—In 1876, 2,200 tons of tin ore were stamped yielding over 1 per cent. of black tin per ton.||

BARNCOOSE MINE.—A quantity of rich copper and tin ore was raised from this mine, but it was suspended in 1872 owing to poverty. At the 50-fathom level the lode is 3 feet wide, and consists largely of mundic and quartz.

The Mowhay Lode underlies north, and is thought to be a continuation of Dunkin's Lode (in Cook's Kitchen). The *Barncoose Lode* underlies north about 15 deg.¶

WHEAL BASSET AND GRYLLS.—*Tyack's Lode.*—The lode varies in width from 2 to 3 feet, and has yielded tin ore from surface to the 64-fathom level.

Wheal Fat Lode.—Varies in width from 3 to 10 feet. Has yielded tin ore.

Brenton's Lode.—From the 22 to the 52-fathom level the lode varies in width from 2 to 6 feet, and has yielded tin ore.

Furgenson's Lode.—4 feet in width. From the 23 to the 50-fathom level the lode yielded good tin ore.

South Tymorgie Lode.—3 feet in width at the 30-fathom level.

Tymorgie Branch.—From the 34 to the 44-fathom level the lode varies in width from 1 inch to 2 feet.

Caunter Lode.—At the 30-fathom level the lode is 5 feet in width and yielded tin ore. A horse of ground occurred in this lode.

Wilkin's Lode.—From the 20 to the 60-fathom level the lode is 2 feet wide.

Cope's Lode.—From 1 to 2 feet in width at the 35-fathom level and yielded fair tin ore. The lode at the 65-fathom level is 3 feet in width. North branch is 1 foot wide, but yielded no tin ore.

Garlidna Lode.—At the 11-fathom level the granite was encountered in the south wall.

* J. Maynard, "Remarks on Two Cross Sections." *Rep. Corn. Poly. Soc.*, 1871, p. 202.
† Foster.
‡ Phillips and Darlington. "Records of Mining and Metallurgy," 1857.
§ Henwood. || Foster, p. 648. ¶ Thomas.

Harvey's Lode.—At the 20-fathom level the lode is 2 feet in width and yielded poor ore.

Wheal Foster Lode.—From the 15 to the 35-fathom level the lode is 1 or 2 feet in width, with a little tin ore.

WHEAL BEAUCHAMP.—There were five lodes worked about the year 1819. The most northerly underlies north and yielded copper. The next was wrought for both tin and copper. Underlies N. 15 deg. The two next yielded copper ore. They underlie north. The southernmost was wrought for tin ore and underlies N. 13 deg.*

BELL MINE.—A copper lode underlies N. 23 deg. (Thomas.) At the 20-fathom level the leader is 18 inches wide.

WHEAL BOYS.—A copper lode underlies S. 15 deg. (Thomas.)

WHEAL BULLER.—Charles Thomas states that the dividends from the sales of copper ore since its discovery in quantity at the 20-fathom level up to the year 1867, were £270,000.† In 1820 and 1821, 972 tons of copper ore were raised yielding 97 tons of copper.‡

WHEAL BULLER AND BEAUCHAMP. — Henwood gives the following particulars of the lodes of this mine:—

South Lode.—Bearing E. 25 deg. N. Underlie 15 deg. to 30 deg. N., varies in width from 1 to 2 feet. Black copper ore with quartz, felspar, and earthy brown iron ore.

North Lode.—Bearing E. 25 deg. N. Underlie N. 10 deg. to 30 deg. Yielded black and vitreous copper ores to the 50-fathom level.

Davey's Lode.—E. 27 deg. N. Underlie vertical to 45 deg. N. Varies in width from 1 to 20 feet. The lode contained quartz, slate, black and vitreous copper ores, copper pyrites, oxide, carbonate and arseniate of copper, fluorspar, and chlorite. At the 99-fathom level there were veins of quartz and copper pyrites.

CARDREW DOWNS MINE.—Henwood makes the following statement in regard to the lodes:—

South Lode.—Bearing E. 17 deg. N. From the 50 to the 120-fathom level the underlie is N. 10 deg. to N. 30 deg., and the width is from 6 inches to 6 feet. The lode consists of quartz, earthy brown iron ore, black copper, and iron and copper pyrites, chlorite, and fluorspar.

North Lode.—E. 17 deg. N. The underlie is from 8 deg. S. to 22 deg. S. The lode varies in width from 8 inches to 2½ feet, and consists of quartz, chlorite, slate, and iron and copper pyrites.

Phillips and Darlington state that the Cardrew Mine yielded between 1826 and 1838, 17,143 tons of ore containing 1,141 tons of copper.‡

CARHARRACK.—The *Wheal Virgin Lode* underlies N. 16 deg.

Another lode situated further south is said to be a continuation of Wheal Maid lode. (Thomas.)

Between 1820 and 1852, Wheal Maiden and Carharrack yielded 23,552 tons of ore containing 1,542 tons of copper.‡

CARLEEN MINE.—The lode is wide and productive in killas, but immediately it enters the granite it is reduced to a mere string.§ The lode is a continuation of one of those in Wheal Vor.

CARQUEEN MINE.—There is a great cross-course 60 fathoms east of the Engine shaft.

* Thomas.
† "Mining Districts of the West," 1867, p. 53.
‡ Phillips and Darlington. "Records of Mining and Metallurgy," 1857.
§ J. Carne, "On the Veins of Cornwall." *Tr. R.G.S. Corn.*, 1822, vol. ii., p. 93.

THE CHACEWATER MINE (or Wheal Busy).—*William's Lode*.—Underlie S. 15 deg. This lode is known eastwards in Wheal Daniell and westwards in Wheal Chance. It is the South lode of Wheal Chance, Treskerby, Wheal Boys, and Wheal Prussia.

Chacewater Lode.—A tin and copper lode having a northerly underlie of 47 deg. The lode is known in Wheal Daniell, Treskerby, and Cardrew.

Winter's Lode.—A tin and copper lode underlying N. 47 deg. The "black elvan" is situated between this and the Chacewater lode.

Wheal Vor Lode.—Underlies N. 22 deg. A tin and copper lode.* Between 1815 and 1822, 30,140 tons of ore containing 1,882 tons of copper were sold by public ticketing; in 1823, 198 tons containing 16 tons of copper, and between 1823 and 1856, 33,486 tons of ore containing 1,669 tons of metallic copper.† Tin, copper, wolfram, and arsenic occur.

WHEAL CHARLES.—The *North Lode* has a bearing E. 25 deg. N., and has an irregular northerly underlie from the 30 to 70-fathom level. In width the lode is 2 to 10 feet. It consists of quartz, slate, copper and iron pyrites, and earthy brown iron ore. At Bateman's shaft the lode is 3 feet wide but barren.

Stacey's Lode.—Bearing E. 25 deg. N. The underlie is north. The lode consists of copper and iron pyrites, quartz, and slaty clay.‡ Between 1821 and 1834, 4,360 tons of copper ore were sold by public ticketing, containing 283 tons of copper.§

WHEAL CLINTON.—Situated near Trefusis Point, Falmouth. Mr. F. J. Stephens states that the mine was started in 1854 and wound up in 1858, but that prior to this a little work was done on the same lode towards the east. The adit level driven in a long way on the South lode showed traces of lead in many places. In the No. 1 cross-cut "a fine course of ore composed of spar, flucan, and frequent bunches of galena" occurred, but the lode was disordered near greenstone.‖ The same writer states that some ore containing blende and galena was assayed and found to contain silver and "generally a little gold."¶ Sir Warington Smyth in 1857 remarked that Wheal Clinton has been worked beneath the sea between the 20 and 30-fathom level, and that lead ore was raised from the mine at this place. A cross-course at the 20-fathom level made the workings dangerous.**

CONSOLIDATED MINES. (See Figs. 23, 24, 25, and 26.)—The following notes are from Henwood:—

Paul's Lode.—Bearing N.E. and S.W. Underlie 14 deg. to 40 deg. N.W. From the 70 to the 123-fathom level the lode is 2 to 4 feet wide, and contained black and vitreous copper ore, copper and iron pyrites, slate, and quartz.

Glover's Lode or Kitto's Branch.—Bearing E. 25 deg. N. From the 70 to the 215-fathom level the lode has an irregular southerly underlie, varying from 10 deg. to 45 deg. Black, vitreous, and yellow sulphide of copper in slate.

Michell's Lode.—E. 25 deg. N. Underlies 80 deg. S., and is about 2 feet in width. It consists of quartz, slate, and iron and copper pyrites.

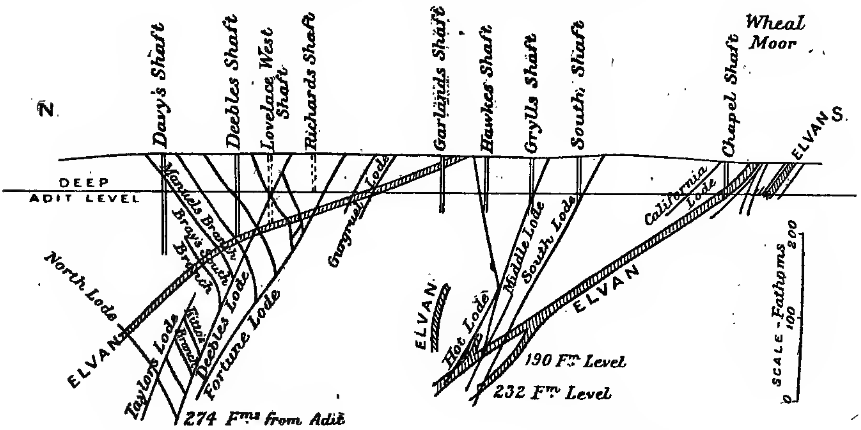
Taylor's Lode.—The bearing from the 150 to the 290-fathom level is E. 27 deg. N. In the upper levels, down to the 240-fathom level, it has an underlie of N. 76 deg. At the 240-fathom level it is vertical. Below this it varies from 16 deg. N. to 20 deg. N. Varies in width from 1 to 16 feet.

* Thomas.
† Phillips and Darlington. "Records of Mining and Metallurgy," 1857.
Henwood.
§ Phillips and Darlington. "Records of Mining and Metallurgy," 1857.
‖ "The Mineral Resources of Falmouth." *Rep. Corn. Poly. Soc.*, 1886, p. 189.
¶ *Tr. R.G.S. Corn.*, 1899.
** Information obtained from an unpublished report through the courtesy of Mr. Crawfurth Smith, of the "Office of Woods," Whitehall.

At the 150-fathom level there was a vug 25 fathoms in length. The lode contains quartz, slate, iron and copper pyrites in detached masses, and in the deeper levels copper pyrites, fluorspar, and quartz.

Elvan's South Lode.—E. 18 deg. S. at the 190-fathom level. It varies in underlie from S. 26 deg. to S. 40 deg. It is 4 to 6 feet in width, and contained quartz, slate, and some copper sulphide.

FIG. 23.—*Clifford Amalgamated Mines.*



Great Consolidated Mines, United Mines.

Tregonning's Lode.—Bearing N.E. and S.W. From the 165 to the 228-fathom level the lode underlies S.E. 20 deg. to N.W. 12 deg. Varies in width from 3 to 6 feet, and contains quartz, copper sulphide, and slate.

FIG. 24.—*Poldice.*

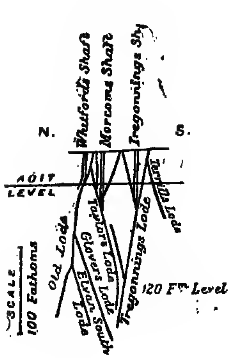
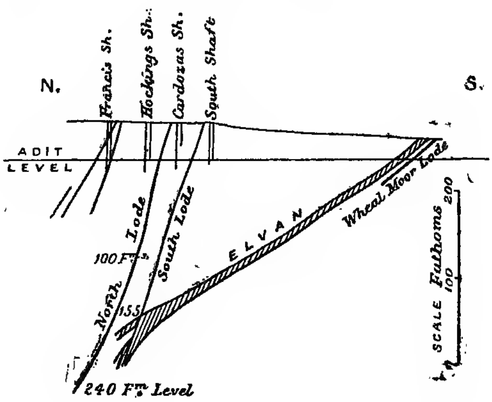


FIG. 25.—*United Mines.*



Deeble's North Lode.—Bearing N. 35 deg. E. From the 250 to the 260-fathom level the lode varies in underlie from 10 deg. to 22 deg. N., and in width from 1 to 4 feet, consisting of copper sulphide, chlorite, and quartz. It unites with Deeble's lode westwards.

Deeble's Lode.—From the 40 to the 285-fathom level the lode varies in underlie from N. 20 deg. to S. 10 deg. From 2 to 6 feet in width. At

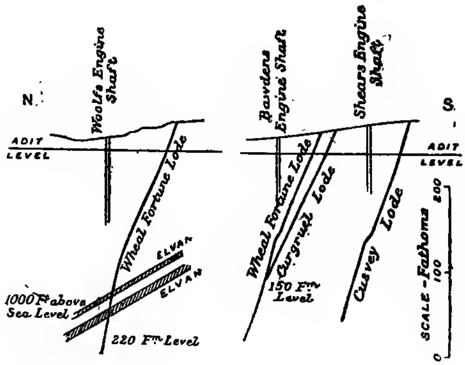
the 40-fathom level the lode contains earthy brown ores, quartz, copper pyrites, and black copper ore. In depth it is mainly copper pyrites with quartz. The lode joins the Wheal Fortune lode eastwards.

Wheal Fortune Lode.—E. 36 deg. N. From the 160 to the 285-fathom level the underlie is N. 30 deg. to vertical, and the lode contains iron and copper sulphide and some earthy brown iron ore at the 250-fathom level. The shoots of copper dip east. In the eastern part of the mine the lode has the same bearing, and from the 145 to the 215-fathom level the underlie is N. 4 deg. to N. 30 deg., varying in width from a few inches to 14 feet. At the 160-fathom level the lode contains earthy brown iron ores and some copper pyrites, and quartz in some places mixed with schorl. There is also chlorite in vuggy quartz.

Cusvey Lode.—Bearing E. 32 deg. N. The underlie is 10 deg. to 32 deg. N. from the 33 to the 173-fathom level. The lode varies in width from 6 or 7 inches to 3 feet, and contains copper and iron pyrites, quartz, chlorite, and schorl. The ore shoots dip east.

Between 1815 and 1856, the ore sold by public ticketing from this mine amounted to 441,286 tons containing 37,402 tons of metallic copper.*

FIG. 26.—*Consolidated Mines.*



CRANE AND BEJAWSA MINE.—The Wheal Seton main lode as well as that of South Roskear Mine traverses this sett.

The Bejawsa Lode underlies north from surface to the 20-fathom level, but below that it underlies south. It varies in width from 2 to 4 feet, and has a fair gossan with quartz and mundic.

The Crane Lode varies in thickness from 18 inches to 3 feet. The lode generally is poor, but yielded blende, copper ores, and some lead with iron pyrites in the higher levels. It was explored to the 60-fathom level.

The Briggan Lode contains copper ore with quartz and chlorite.

Charles Thomas states that the West Seton main lode was worked to the 100-fathom level in this mine but only yielded a little copper ore. The elvan which traverses the West Seton Mine passes through this sett and is in contact with the lode.† Between 1851 and 1853, 671 tons of copper ore containing 61 tons of copper were sold by public ticketing.‡

CRENVER AND WHEAL ABRAHAM AND SARAH.—The lode is 2½ to 3 feet in width and has an east and west bearing. It underlies south 15 deg. It becomes poor and hard and often divided into branches in the elvan, and

* Phillips and Darlington. "Records of Mining and Metallurgy," 1857.
† "Mining Districts of Cornwall," 1867, p. 47.
‡ Phillips and Darlington. "Records of Mining and Metallurgy," 1857.

in fact "an elvan appears to be one of the components of the lode."* In some parts of Crenver and Wheal Abraham the ore shoots have a westerly pitch.† The mine has been worked to a depth of 220 fathoms at the Old Sump (or Middle Engine) shaft. Between 1815 and 1827, 85,851 tons of copper ore containing 6,061 tons of copper were sold by public ticketing from Wheal Abraham, Oatfield, and Crenver. Wheal Abraham in 1854 yielded 324 tons of ore containing 5 tons of copper.‡

WHEAL CUPID.—The Wheal Cupid lode is copper bearing and underlies S. 13 deg. Another copper lode situated on the south underlies N. 13 deg. On the north of the Wheal Cupid lode there is a lode underlying north. (Thomas.)

WHEAL DAMSEL.—The *Main Lode* has been traced for over 2 miles, and is the same as the Wheal Maid lode.§ All the lodes have yielded copper ore.

The Pressure Engine Lode underlies N. 13 deg.

The Old North Lode underlies N. 27 deg.

The Old South Lode underlies N. 23 deg.

Gilbert's Lode underlies N. 13 deg.

Turtle's Lode underlies N. 12 deg.

Wheal Hope Lode underlies N. 15 deg.‖

Between 1815 and 1842, 25,111 tons of ore containing 3,176 tons of copper were sold by public ticketing.¶

WHEAL DANIELL.—The upper part of the lode was worked for tin for at least 10 fathoms. The lode did not yield copper near the surface.** It has been worked to the 48-fathom level. Thomas has recorded the following particulars regarding the lodes:—

Chacewater Lode nnderlies N. 40 deg. Wrought for tin ore.

Winter's Lode situated north of Chacewater lode underlies N. 40 deg. Wrought for tin and copper.

William's Lode underlies S. 32 deg. Wrought for copper.

South Lode underlies N. 17 deg. Wrought for tin and copper. Thirty fathoms south of the South lode is the *Fat Sow Lode* which underlies north; tin bearing. Thirty fathoms south of the Fat Sow lode is the *Wheal Doit Lode* which underlies north; tin and copper bearing.

WHEAL DERRICK.—The *North Carquean Lode* underlies N. 27 deg. The lode yielded both tin and copper. There are three other lodes which have been wrought for copper ore. They underlie north or are perpendicular. (Thomas.)

EAST ALE AND CAKES MINE.—The United Mines Great lode passes into this sett. It underlies N. 15 deg. The *South Lode* underlies N. 37 deg. (Thomas.)

EAST WHEAL CHANCE.—A copper lode underlies south 13 deg. A *Caunter Lode* bearing copper ore underlies N. 4 deg. and heaves the main lode 2 fathoms to the left. (Thomas.)

EAST DOWNS.—*Trewan North Lode* (*Briggan Lode*) underlies S. 15 deg. The *South Lode* underlies south at the same angle. (Thomas.)

EAST WHEAL DAMSEL.—The *North Lode* strikes E. 17 deg. N. From the 80 to the 150-fathom level it varies in width from 1½ to 12 feet, and underlies N. 6 deg. to 22 deg. The veinstone is composed of quartz, felspar, clay, iron pyrites, and vitreous and black copper ores.

* J. Carne, "On Elvan Courses." *Tr. R.G.S. Corn.*, 1818, vol. i., p. 101.

† Henwood, p. 41.

‡ Phillips and Darlington. "Records of Mining and Metallurgy," 1857.

§ J. Carne, "On the Veins of Cornwall." *Tr. R.G.S. Corn.*, 1822, vol. ii., p. 121.

‖ Thomas.

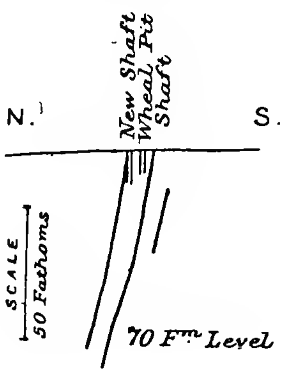
¶ Phillips and Darlington. "Records of Mining and Metallurgy," 1857.

** W. H. Argall. Miners' Association (Breage Meeting), 1872.

Middle Lode.—E. 17 deg. N. From 100 to 180-fathom level the lode varies from 2 to 7 feet and underlies 10 deg. to 30 deg. N. It consists of decomposed granite, vitreous and black copper ore, copper sulphide, iron pyrites, and earthy red iron ore. (Henwood.)

East Wheal Lovell. (Fig. 27.)—Mr. Collins has described some of the lode material from this mine. He remarks that it was originally granite, but the felspar is changed to a dusty-looking material, which under high powers of the microscope seem to be imperfectly formed crystals of gilbertite and perhaps a little tourmaline. In places, in the neighbourhood

Fig. 27.—*East Wheal Lovell.*



of these greyish spots, there are very distinct needles of tourmaline and radiating flakes of gilbertite. There is quartz, with fluid cavities, which includes a little black opaque mica with irregular crystals and granules of cassiterite.* Two lodes appear to form a junction westwards. The upper part of the lodes for 17 fathoms were worked by the old men, but it was since worked to the 127-fathom level.

East Wheal Seton and Wheal Emily Henrietta.—Before 1860, Wheal Emily Henrietta was known as Tolvaddon Old Mine. Copper ore was raised from the 40 to the 70-fathom levels.†

Cock's Lode.—At adit level, this lode is 1 to 2 feet in width, and consists of quartz and mundic. At the 40-fathom level, it is 5 feet wide and was fairly rich in copper ore.

The Main Lode of Wheal Emily Henrietta underlies N. 15 deg., from surface to the 30-fathom level, but is not so steep in the western part of the mine. It varies in width from 1 to 4 feet. At adit level the lode is 2 to 4 feet wide and contained blende and copper ore with quartz. From the 44 to the 70-fathom level the veinstones were chloritic and quartzose, with fair to poor copper ore.

East Wheal Sparnon.—*Wheal Sparnon Lode* underlies south 15 deg. and intersects an elvan. It is a copper-bearing lode 4 or 5 feet wide. The *Cal Lode* carries tin and underlies south at 23 deg. (Thomas.)

East Tresavean.—A copper lode underlies north. (Thomas.)

* J. H. Collins, "Cornish Tinstones and Capels." *Min. Mag.*, 1882, vol iv., p. 10.

† J. Maynard, "Mines in the Illogan District." *Rep. Roy. Corn. Poly. Soc.*, 1874, p. 84.

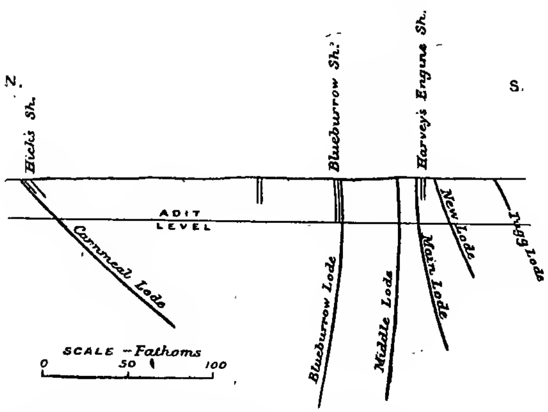
WHEAL FALMOUTH.—The lode strikes E. 40 deg. N. and underlies S.E. 20 deg. to 46 deg. From the 30 to the 70-fathom level the lode consists of chlorite, decomposed slate, and earthy brown iron ores, copper and iron pyrites, and at the 50-fathom level phosphate of iron. Also blende, purple copper ore, galena, &c. (Henwood.) Between 1829 and 1833, 1,808 tons of ore containing 87 tons of copper were produced.*

WHEAL FANCY.—Abandoned in 1850. In adit the lode is 4 feet wide and contains copper and iron pyrites and quartz. In shallower parts of the lode ore was obtained.

WHEAL FOREST.—The lode has an underlie 13 deg. S. to the 45-fathom level and varies in width from 6 inches to a foot, but is 2 feet wide in some places. The lode is an altered elvan on the west of the Engine shaft and is richer here than in other places. The ore extracted was largely mundic, associated with quartz and flucan, which was very ferruginous.

WHEAL FORTUNE (Breage). (Fig. 28.)—Tin ore occurred in killas. Collins states that the dark greyish brown killas is spotted and banded with white quartz, with light yellowish grey macled crystals of cassiterite in the joints, varying from $\frac{1}{4}$ to $\frac{1}{12}$ of an inch across, and mingled with gilbertite.†

FIG. 28.—*Great Wheal Fortune.*



The Carnmeal Lode underlies south. The best piece of ore ground on this lode is between Hoskin's and Painter's shafts about the 68-fathom level. The lode is 4 feet wide consisting of peach and quartz. The Wheal Vor lode also traverses the sett but underlies north.‡

WHEAL FRIENDSHIP (Wh. Andrew).—The *Great Lode* underlies north 13 deg. It is a continuation of the lode which traverses the United Mines.

The North Lode underlies N. 5 deg. It is a branch of the Great lode. There are two other copper lodes further north.

Wheal Fortune Lode traverses this sett. In Wheal Fortune it was worked for zincblende.

South Lode underlies N. 13 deg. and contains tin ore. It is a south branch of the Baldhu lode. (Thomas.)

GARLIDNA MINE.—Worked to the 70-fathom level.

* Phillips and Darlington." "Records of Mining and Metallurgy," 1857.
† J. H. Collins, "Cornish Tinstones and Capels." *Min. Mag.*, vol iv., 1882, p. 15.
‡ H. C. Salmon. *Min. and Smelt. Mag.*, 1862, vol. ii., p. 17.

WHEAL GORLAND. (Fig. 29.)—*Gossan Lode* (copper) underlies N. 27 deg. It was known as Cain's lode in Wheal Unity.

Unity Lode (copper) underlies N. 27 deg.

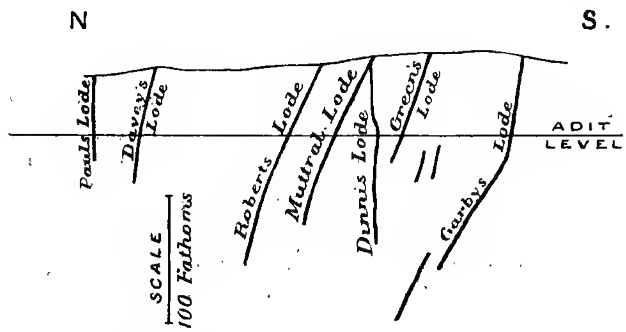
Green's Lode (copper) underlies N. 27 deg.

Dennis Lode (copper). Vertical. It crosses Green's lode.

The Muttral Lode is a tin lode situated 10 fathoms north of Unity lode. It underlies N. 23 deg.

North Lode (copper) underlies N. 13 deg.

FIG. 29.—*Wheal Gorland.*



Paul's Lode (copper) underlies N. 5 deg. Situated N.W. of the North lode. (Thomas.)

The principal lode of Wheal Gorland has been traced for 2 miles and passes through Wheal Unity and Creegbraws.* Fluorspar has been raised in great quantity. In 1884 it realised £1 a ton when sold to Swansea smelters.† Captain Hambley assayed some of the gossan of Wheal Gorland and found that it contained 6 dwts. of gold and 2 dwts. of silver per ton, also 15·5 per cent. of wolfram.‡ Between 1815 and 1851, 40,751 tons of ore containing 3,234 tons of copper were sold by public ticketing.§

WHEAL GRAMBLER.—The mine contains the easterly extension of the lodes found in Pedn an Drea Mine. Some of the lodes have been worked along their outcrops for tin ore. The *Grambler Lode* has a rich gossau, below which good copper and tin ores were wrought. The water level in the mine is about 13 fathoms from surface. Between 1843 and 1856, 7,261 tons of ore containing 569 tons of copper were sold from Grambler and St. Aubyn by public ticketing.‖

GREAT NORTH SETON.—The lode underlies N. 13 deg. It is 2 to 3 feet in width and has a fine gossan. Copper and tin ore with mundic were wrought. In depth the veinstone is a dark, hard, heavy capel with quartz.

GREAT SOUTH TOLGUS.—The *Main Lode* at 100-fathom level was from $1\frac{1}{2}$ to 2 feet wide and contained copper and mundic in a quartz veinstone. At the 125-fathom level the copper lode is supposed to have been thrown 90 fathoms to the right. In 1855 and 1856, 1,770 tons of ore were sold containing 110 tons of copper.¶

* J. Carne, "On the Veins of Cornwall." *Tr. R.G.S. Corn.*, 1882.
† Brenton Symons. "A Sketch of Geol. of Cornwall," 1884.
‡ F. J. Stephens, "Recent Discoveries of Gold in West Cornwall." *Tr. R.G.S. Corn.*, 1899.
§ Phillips and Darlington. "Records of Mining and Metallurgy," 1857.
‖ *Ibid.* ¶ *Ibid.*

GUARNECK MINE (Garras).—The mine was worked in 1720 and some of the lead ore yielded 100 ozs. of silver per ton.* It was again worked in 1814 and in two years produced 800 tons of silver-lead ore containing 13 parts of lead in 20 of ore. The lead contained 70 ozs. of silver per ton. The lode runs N.N.E. and S.S.W. and is about 2½ feet wide. It is heaved twice by two slides each of which throws the lode 6 fathoms. The ore richest in silver was found near these slides at the 70-fathom level.†

GUSTAVUS MINE.—The south underlying lode was intersected in the shaft about the 35-fathom level. The lode varies in width from 2 to 4 feet and is quartzose. At the 76-fathom level it was so poor that it was abandoned. In 1853, 89 tons of ore containing 6 tons of metallic copper were sold by public ticketing.‡

HALABEZACK FARM.—The produce of black tin varied from 10 to 56 lbs. per ton.§

HALLENBEAGLE MINE.—*Hallenbeagle Lode* (copper) underlies S. 15 deg. It is recognised in Wheal Rose, Hawke, and Messar.

South Lode (copper) underlies S. 13 deg.

Between these are two other lodes:—*Raby's Lode* (copper) underlies N. 13 deg. *William's Lode* (copper) underlies S. 23 deg. (Thomas.) Between 1835 and 1846, 30,576 tons of ore containing 1,803 tons of copper were sold by public ticketing.‖ The mine is worked to the 70-fathom level.

WHEAL HARMONY (or TRELEIGHWOOD) MINE.—Wolfram occurred in this mine.¶

Great Lode (tin) underlies N. 41 deg.

Another tin lode on the south of the Great lode underlies N. 54 deg.

Wheal Bray Lode (copper) underlies N. 13 deg.

Butler's Lode underlies S. 15 deg.

Butler's North Lode contains tin and copper.

Polkinhorne's Lode (tin) underlies S. 10 deg. (Thomas.)

WHEAL HARRIET.—The mine was abandoned in 1866.

Main Lode.—The Engine shaft is vertical to the 77-fathom level (adit 40 fathoms from surface), but after this it follows the underlie of the lode, which is about 15 deg. N. The lode was not very rich and was poor from 74 to 90-fathom level. At the 115-fathom level it was about 1½ feet wide, and contained tin ore, but at the 130-fathom level it was poor. Cross-cuts were driven from the main lode, both north and south, at the 90-fathom level.

North Lode.—This is 7 fathoms north of the main lode at the 90-fathom level. It was thin and poor but yielded copper ore at adit level. At the 130-fathom level it is 1 to 1½ feet wide and contains tin ore. Between 1835 and 1848, 9,030 tons of ore were yielded containing 496 tons of copper.**

WHEAL HATCHET.—This mine is situated in the south-west part of South Roskear Mine. The lode runs under the main road leading from Tuckingmill to Hayle, and has an irregular but nearly perpendicular underlie. The Engine shaft, which is just north of the road, is perpendicular to the 170-fathom level, and at this place is 2½ feet wide, and contains copper pyrites and fluorspar. The lode varies in width from 1½ to 3 feet.

WHEAL HAWKE.—*Wheal Hawke Lode* (copper) underlies south 23 deg. The lode is recognised in Wheal Rose, Hallenbeagle.

Tenpenny Lode (copper) underlies south 13 deg.

Pendarves Lode (copper) underlies north 23 deg.

* Borlase. *Nat. Hist. Corn.*

† J. Carne, "On the Discovery of Silver in the Mines of Cornwall." *Tr. R.G.S. Corn.*, vol. i., 1818, p. 120.

‡ Phillips and Darlington. "Records of Mining and Metallurgy," 1857.

§ C. Fox, "A Deposit of Tin in Wendron." *Miners' Assoc. Corn. and Devon*, 1868, p. 47.

‖ Phillips and Darlington. "Records of Mining and Metallurgy," 1857.

¶ J. Garby, p. 84.

** Phillips and Darlington. "Records of Mining and Metallurgy," 1857.

Tin Lode underlies north 13 deg. and is crossed by the Wheal Hawke Lode at the 60-fathom level. (Thomas.)

WHEAL JEWELL.—Between 1815 and 1853, 58,160 tons of ore containing 5,222 tons of copper were sold.

Main Lode.—Bearing E. 20 deg. N. Underlie N. 10 deg. to 23 deg. The lode varies in width from 1 to 4 feet from the 20 to the 90-fathom level. It consists of decomposed granite, quartz, felspar, clay, black sulphide of copper, and copper pyrites.

Row's Lode.—Underlies N. 16 deg. to 20 deg. and varies in width from 10 inches to 1½ feet. It consists of quartz, sulphides of iron and copper, and fluorspar. (Henwood.)

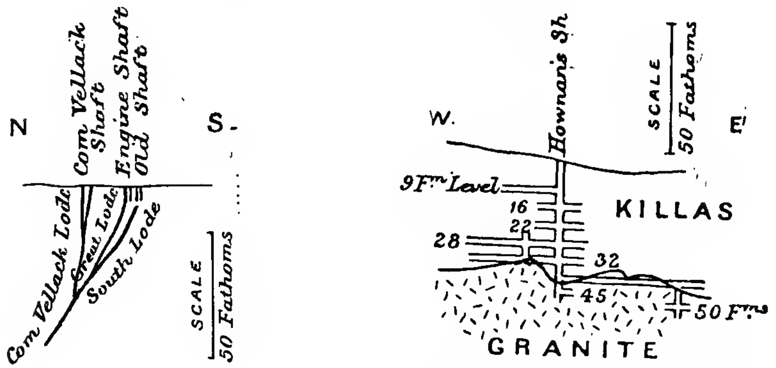
Thomas records the following notes in regard to "Wheal Jewell and Wheal Quick":—

Wheal Quick Lode or *Wheal Jewell North Lode* is the same as the Poldice Great ore lode. In this mine it is split up into Wheal Quick North and South Branches.

The Middle Lode (copper) underlies N. 23 deg. It is situated south of Wheal Quick lode.

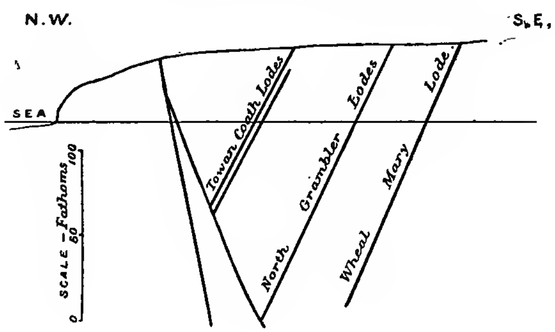
South Lode (copper) underlies N. 23 deg.

FIGS. 30 and 31.—*The Lovell Mine.*



Longitudinal Section of South Lode.

FIG. 32.—*Wheal Lushington.*

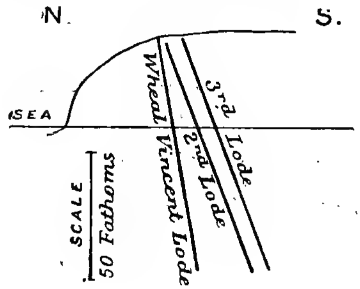


LOVELL MINE.—There are two lodes. The *North Lode* strikes E. 37 deg. to 45 deg. N. and underlies N.W. 20 deg. The *South Lode* strikes E. 48 deg. N. and underlies N.W. 30 deg. The lodes unite as they go east, as also in depth.* (Figs. 30 and 31.)

* Foster.

WHEAL LUSHINGTON (NEW DOLCOATH). (Figs. 32 and 33.)—*Wheal Fox Lode.*—An adit has been driven on the lode from Porth Towan Valley. The lode is poor, although extensively explored along the outcrop. It varies in width from 1 to 2 feet.

FIG. 33.—*Wheal Vincent (part of Wheal Lushington).*



WHEAL MAID. — The *Wheal Maid Lode* (copper) underlies south to the 30-fathom level, after which it underlies N. 13 deg. (Thomas.)

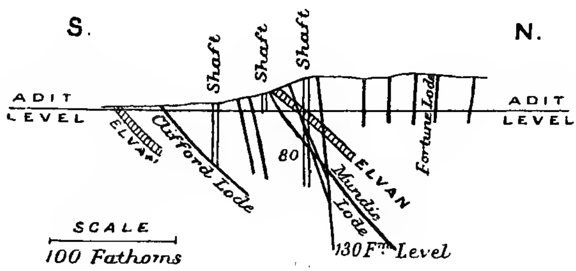
WHEAL MARIA.—The *Good Success Lode* (or *John's Gossan*) is a lode containing copper ore and underlying N. 23 deg. Situated to the north, there is a copper branch underlying south 10 deg. (Thomas.)

WHEAL MARY.—*The North Lode* (copper) underlies S. 13 deg.
The Middle Lode (copper) underlies S. 10 deg.
The South Lode (copper) underlies S. 13 deg. (Thomas.)

MEDLYN MOOR MINE.—Worked to a depth of 33 fathoms.

NANGILES. (Fig. 34.)—The *Baldhu Lode* (tin) underlies N. 45 deg. The lode splits as it goes west. The north part westwards is the main lode in South Ale and Cakes Mine. The south part is the South lode in Wheal Friendship.

FIG. 34.—*Nangiles.*



Nangiles Copper Lode is situated north of the Baldhu lode. The lode splits as it goes eastwards. The north part underlies north 13 deg. and was rich where it traversed a soft elvan but poor in killas. The south branch underlies N. 27 deg. (Thomas.) The gossan of one of these lodes is said to be auriferous.*

* D. Forbes, "Researches in British Mineralogy." *Phil. Mag.*, 1869, vol. xxxvii., p. 322. J. Garby, *Tr. R. G. S. Corn.*, vol. vii., 1848, p. 90.

Between 1845 and 1848, 1,449 tons of ore containing 110 tons of copper were sold by public ticketing from Andrew and Nangiles.*

NEW WHEAL LOVELL.—Worked to the 70-fathom level at Hill's Engine shaft.

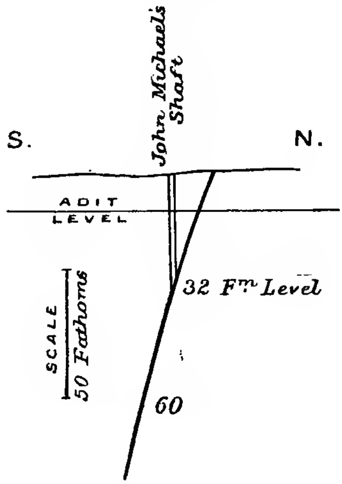
NEW WHEAL SETON.—The *Main* or *West Seton Lode* has a good gossan and near the surface it is 6 feet wide. At the 62-fathom level the lode is 2½ to 3 feet in width. The veinstone consists of chlorite, quartz, copper ore, and mundic. The lode lies next to an elvan which underlies northwards, with the lode on the foot wall side.

NEW WHEAL VIRGIN.—*New Wheal Virgin Lode* (copper) underlies N. 10 deg.

North Lode (copper) underlies N. 13 deg.

One hundred and fifty fathoms further north there is the *Clyjah Lode* (tin) which underlies N. 13 deg., while 20 fathoms further north there is a copper lode which is said to be a continuation of Wheal Virgin and Wheal Hope lode. (Thomas.)

FIG. 35.—*North Downs.*



NORTH DOWNS. (Fig. 35.)—The mine was worked to the 143-fathom level or 110 below adit at the Water Engine shaft.

John's Gossan Lode.—E. 21 deg. N. Underlies N. 18 deg. to 30 deg. The lode is 1½ feet wide at the 30-fathom level, and consists of quartz, earthy brown iron ore, and iron pyrites.

Wheal Peevor Lode.—E. 12 deg. N. Underlies S. 12 deg. to 20 deg., and consists of quartz, clay, and slate.

Main Lode.—E. 14 deg. N. Underlies S. 8 deg. to 20 deg. Consists of copper pyrites, limonite, iron pyrites, blende, slate, and granular quartz.

Tenpenny Lode.—E. 30 deg. N. At the 30-fathom level the lode is vertical and 1½ to 2 feet in width. Copper and iron pyrites, quartz, and earthy iron ores.

Caunter Lode.—E. 28 deg. N. At the 30-fathom level the lode underlies N. 7 deg. to 10 deg. It varies in width from 1 to 2 feet, and consists of earthy iron ore, iron and copper pyrites, and slaty clay.

* Phillips and Darlington, "Records of Mining and Metallurgy," 1857.

Pendarves Lode.—E. 22 deg. N. At the 30-fathom level the lode is vertical and is about 1 to 1½ feet in width. Contains tin ore with iron pyrites and earthy brown iron ore and slate. (Henwood.)

Between 1815 and 1855, 19,348 tons of ore containing 1,600 tons of copper were sold by public ticketing.*

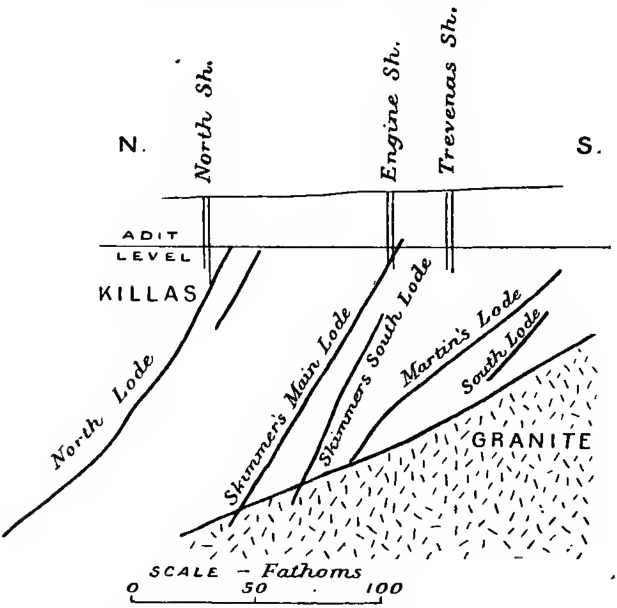
NORTH WHEAL JANE.—Worked to the 40-fathom level on the tin lode, and to the 10-fathom level on the lead lode.

NORTH POOL.—Yielded copper ore, but was never worked for tin.

NORTH ROSKEAR.—Between 1816 and 1856, 151,797 tons of copper ore containing 11,846 tons of copper were sold by public ticketing. In 1841, copper ore, sold at £7 5s. a ton, realised £28,850.

At the 205-fathom level, west of Doctor's shaft, the lode is 2½ feet wide, and consists of quartz with copper pyrites and tin ore. At the 216-fathom level the lode was from 1 to 8 feet wide and contained quartz, fluorspar,

FIG. 36.—*Pedn an Drea Mine.*



chlorite, tin, and copper. At the 203-fathom level there was tinstone and mispickel, but little or no copper. In the eastern part of the mine, on the east of the Engine shaft at the 160-fathom level, the lode is 4 feet wide and contains copper and tin ore. A hot spring of temperature 102 deg. F. made the "end" at this level too hot to work in, the temperature of the air being about 100 deg. F. The Engine shaft is sunk below the 110-fathom level. Charles Thomas states that good tin and copper ore occurred in the mine in scattered bunches.‡

Henwood remarks that the *North Roskear Lode* bears E. 32 deg. N. and underlies N. 8 deg. to 22 deg. It varies in width from a few inches to 5 feet. The lode contained copper sulphide, fluorspar, quartz, chlorite, and iron pyrites. The *South Lode* has a bearing E. 32 deg. N. At the

* Phillips and Darlington. "Records of Mining and Metallurgy," 1857.
‡ "Mining Districts of Cornwall," 1867, p. 49.

37-fathom level the underlie is N. 45 deg. to 50 deg. At the 57-fathom level it is 6 deg. to 36 deg. south. It contains quartz, blende, copper, and iron pyrites.

The Main Lode, in the Park an Bowan part of the mine, underlies N. 35 deg. to 40 deg., and is about 1 foot wide. The veinstone is a soft killas with mundic. The *Caunter Lode* was fair in copper and blende, at 70 fathoms west of its junction with the main lode, and varies in width from 1 to 3 feet.

PEDN AN DREA. (Fig. 36.)—Thomas makes the following observations :--

North Tin Lode.—Underlies N. 30 deg.

The next lode on the south yielded copper. It underlies N. 15 deg.

Pedn an Drea Lode (tin).—Underlies N. 30 deg.

Michell's Gossan (copper).—Underlies S. 23 deg.

In 1821, 14 tons of copper ore containing 1 ton of copper were sold by public ticketing. Yielded mainly tin ore. (See p. 165.)

PENDARVES UNITED (or Carnemough).—The sett includes the old Tryphena Mine, Tolcarne (or West Wheal Grenville), and Condurrow Mine.

Condurrow Mine Main Lode.—From the 140 to the 155-fathom level the lode is 6 feet wide, 3 feet of which consists of flucan. At the 266-fathom level it is 2 to 3 feet wide. The leader of the lode varies from 10 inches to 2 feet in width and contains fluorspar, copper, and tin ore. At the 165-fathom level at Pryce's shaft the lode is 5 feet wide and consists of fluorspar, quartz, peach, and some iron and tin ore in capel of north wall.*

Pryce's shaft was sunk on a lode 2½ to 3 feet in width. At the 140-fathom level it is 3 feet wide, and consists of capel, peach, and flucan, with yellow copper ore and tin. At this level a great deal of water was met with possessing an acrid taste, owing to the presence of copper salts, which, reacting upon metal work in the shaft, caused the precipitation of copper upon it. At the 20-fathom level a "pipe" of malleable copper was found which was 18 feet in height, 8 feet in length, and 3 to 15 inches in width.†

At Woolf's shaft at the 200-fathom level there were branches of copper pyrites and grey copper ore in the tin lode. Salmon states that at the 140-fathom level the leader is 10 inches in width. The remainder of the lode is made up of ferruginous capels, plentifully speckled with quartz. These capels have no regular walls, but pass insensibly into the granite of the "country," and as they are stanniferous they are considered to be "lode" by the miners.‡ At the 155-fathom level a large vug occurred in the lode; its dimensions were 36 feet in length, 12 feet high, and 2 to 3 feet wide.

Llandower Lode.—The lode yielded both copper and tin ore at the 30-fathom level. Copper ore was plentiful at the 50-fathom level. It varies in width from 1 to 4 feet.

Robert's Lode.—Hope's shaft from 100-fathom level to the 177-fathom level is sunk on Robert's lode, which varies from 2 to 4 feet in width, and yields tin ore. A Caunter lode branches off at the 90-fathom level in a north-westerly direction.

Caunter Lode.—At deep adit it is 15 inches in width. The lode has a good gossan extending below the 10-fathom level and yielded grey copper ore. It is 2½ to 4 feet wide.

South Lode.—Yielded copper ore at the 60-fathom level.

Field's Lode (in Tolcarne).—Has a good gossan.§

Between 1818 and 1856, 20,095 tons of ore containing 1,498 tons of copper were sold by public ticketing.‖

* H. C. Salmon. *Min. and Smelt. Mag.*, 1863, vol. iii., p. 82.

† E. W. W. Pendarves, "Notice of the Native Copper at Condurrow Mine." *Tr. R.G.S. Corn.*, vol iii., 1828, p. 333.

‡ *Min. and Smelt. Mag.*, 1863, vol. iii., p. 82.

§ H. C. Salmon. *Min. and Smelt. Mag.*, 1863, vol. iii., p. 82.

‖ Phillips and Darlington. "Records of Mining and Metallurgy," 1857.

PENNANCE MINE.—Situated about 1½ miles west of Swanpool. Tin, copper, and lead were found, but although several lodes were cut there was nothing of value discovered. In one trial the lode was 6 inches wide, irregular and very gossany, with quartz and traces of lead ore.*

WHEAL PEEVOR.—*John's Gossan Lode* (copper), underlies N. 30 deg. This lode is recognised in Good Success Mine and Wheal Maria.

Wheal Peevor Lode (tin), 8 to 10 feet in width.† Underlies S. 23 deg. This lode is faulted by John's Gossan lode to the extent of 8 fathoms.‡

Diamond Lode (tin), underlies south 5 deg. (Thomas.)

Wheal Peevor lode is also traversed by two slides both underlying north. It is faulted by them 14 feet and 9 feet respectively.§ It is also heaved by two cross-courses.

WHEAL PINK.—*Wheal Pink Lode* (copper), underlies N. 13 deg. (Thomas.)

Between 1821 and 1850, 1,881 tons of copper ore containing 158 tons of copper were sold by public ticketing.‖

POLDICE.—*Great Ore Lode* (copper), underlies N. 15 deg. In Wheal Jewell and Quick it is the North lode.

Poldice Tin Lode.—Underlies S. 15 deg. It is intersected and heaved two fathoms by the Great ore lode in the western part of the mine.

Bissoe Tin Lode.—Underlies S. 23 deg. At the 80-fathom level it is intersected by the Great ore lode.

Quick's Lode (tin and copper).—It has an irregular but nearly vertical underlie.

Kitty Billing's Lode (copper).—Nearly vertical.

Garby's Lode (copper).—Underlie N. 10 deg.

Holman's Lode (copper).—Underlie N. 10 deg. (Thomas.) The lodes have been traced for two miles. (Carne.)

Between 1815 and 1852, 2,992 tons of copper ore containing 208 tons of copper were sold by public ticketing.¶ (See p. 224.)

POLLADRAS DOWNS MINE.—*Bor* or *Engine Lode.*—E. 35 deg. N. underlies N. 12 deg. to 34 deg. The lode varies from a few inches to 3 feet in width, and consists of slaty quartz, veinstone, with clay and strings of cassiterite, down to the 113-fathom level, where some iron pyrites also occurred.

Bissa or *Penhale Lode.*—E. 30 deg. N. Underlies N. 8 deg. to 40 deg. and varies in width from 2 to 5 feet. In the upper levels it consists of earthy brown iron ore, tin ore, quartz, and quartzose slate. At the 83-fathom level there were veins of quartz and strings of cassiterite in the slate.

Pressure North Lode.—E. 30 deg. N. Underlies N. 16 deg. to 34 deg. and consists of quartz, slate, and cassiterite at the 83-fathom level.

Pressure South Lode.—E. 30 deg. N. The lode consists of quartz and slate and felspar clay. Cassiterite at the 83-fathom level occurs in irregular spots.

Richard's Lode.—E. 30 deg. N. Underlies N. 14 deg. to N. 18 deg. About 4 inches wide, and consists of slaty clay with quartzose, slate, and cassiterite. (Henwood.)

PORKELLIS UNITED MINES. (Fig. 37.)—The lodes have a general underlie north.

Crowan Lode and Harris Lode underlie north, but are nearly vertical. They are 2 to 3 feet in width, and yielded tin ore in fair quantity.

Horseflesh Lode.—South of Crowan lode and said to be a branch of the Tymorgie lode which lies further south. Towards the east this lode and

* F. J. Stephens, "Mineral Resources of Falmouth." *Rep. Corn. Poly. Soc.*, 1886.

† J. Hawkins, "On the Intersection of Lodes." *Tr. R.G.S. Corn.*, vol ii., 1822, p. 240.

‡ J. Carne. § *Op. cit.*

‖ Phillips and Darlington. "Records of Mining and Metallurgy," 1857.

¶ *Ibid.*

the Tymorgie lode unite. It underlies north, and is a fair tin lode about 1½ feet in width.

Great Tymorgie Lode.—Tin was found in the outcrop, but the lode is only fair. It varies in width up to about 3 feet and underlies north 35 deg.

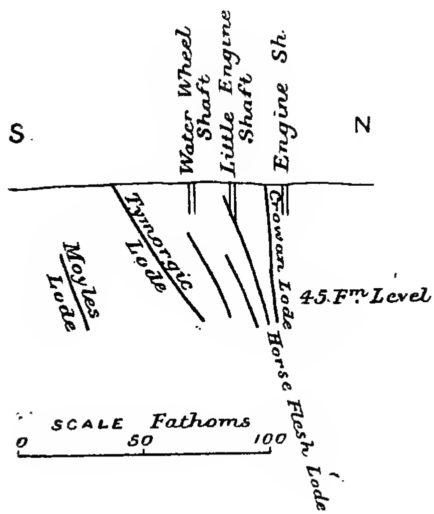
North Tymorgie Lode.—At the 24-fathom level it is as wide as 5 feet in some places, and the lode yielded tin ore to the 50-fathom level.

Wheal Ash Lode.—The most southerly lode is 1 to 2 feet in width, and has a northerly underlie.

Dates Lode.—A good bunch of tin ore was found near Wheal Ash shaft.

North Lode.—South of North Tymorgie lode. Worked to the 80-fathom level. The lode varies in width up to 7 feet and was richer in tin ore in the upper levels than in depth.

FIG. 37.—*Porkellis United Mines.*



South Tymorgie Lode.—2 to 4 feet in width. An elvan which traverses the sett is supposed to be a continuation of one in Wheal Vor.*

PROVIDENCE MINE.—The mine has been worked for tin and copper but is poor. It was abandoned in 1867.† Thomas states that it is the same lode as that worked in Wheal Druid.

WHEAL PRUSSIA.—*Wheal Prussia Lode* (tin).—Underlies S. 27 deg. It is the same lode as the Wheal Vor lode in Treskerby.

Wheal Boys Lode.—Yielded copper. (Thomas.)

WHEAL ROSE (near Wheal Hawke).—*Wheal Rose Lode* (copper).—Underlies S. 27 deg.

Sixty fathoms further south is *Bullfield Lode* (copper), which underlies S. 27 deg. and *Wheal Moyle Lode* (copper), which underlies N. 13 deg. (Thomas.)

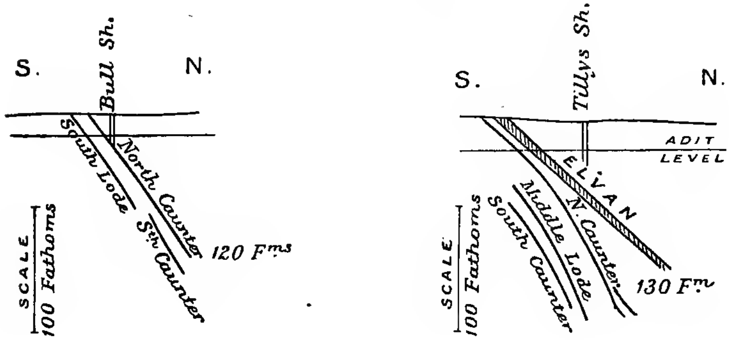
* W. H. Argall, "On Elvan Courses." *Miners' Association*, 1875.

† J. Maynard, "Remarks on a Cross Section." *Rep. Corn. Poly. Soc.*, 1871, p. 200.

ROSKROW UNITED.—The lode is met with 50 fathoms east of the turnpike leading to Ponsanooth village. It is 4 to 6 feet in width, but varies down to about 2½ feet. It underlies north 13 deg. and is explored to the 40-fathom level, where the granite is considered to be only 30 fathoms below. The lode has yielded mundic, with some silver, copper and uranium ores, and also some nickel. An elvan traverses the sett.

SETON, WHEAL. (Figs. 38, 39.)—This mine has yielded mainly copper ores but has produced "a small proportion of tin from its lowest quality or halvan ores."* The workings extend to below the 300-fathom level.

FIGS. 38 and 39.—*Wheal Seton.*



The lode near Tilly's Engine shaft yielded copper ore to the 160-fathom level. From this level to below the 200-fathom level it is mainly a tin lode. Warm water issued from the lode at the 170-fathom level east of Bull's shaft.

South Caunter Lode.—At the 140-fathom level west of Tilly's shaft the lode is 4 feet in width and tin bearing.

North Caunter Lode.—The lode is tin bearing from the 170 to the 200-fathom level, and consists of quartz, capel, and mundic. The *North* (or *Great*) *Caunter* is the same lode as Reeves' lode eastwards, but it is heaved by a cross-course in Wheal Seton sett 20 to 25 fathoms. Westwards this lode assumes a bearing approximating to that of the ordinary lodes of the district.†

Middle Lode.—At the 110-fathom level the lode yielded tin ore and varied in width from 2½ to 4 feet.

Phillips has described the killas at the 160-fathom level. It is a very hard grey clay slate in which the cleavage has been obliterated to some extent, in the majority of cases by metamorphism. No crystalline structure can be detected by the eye, and the rock in addition is traversed by quartz strings enclosing minute spots and crystals of iron pyrites. The microscopic section shows bands of transparent granular quartz alternating with layers of similar quartz through which minute hornblende crystals are disseminated.‡

At the same level Harry Tilly describes a thermal spring, and states that the killas in its neighbourhood is traversed by joints and is not far from the Great cross-course. Thirty gallons of water per minute, at a temperature of 94 deg. F., issues from the lode. The lode is small and contains copper, quartz, and mundic. The water has specific gravity 1·105, and contains

* C. Thomas. "Mining Districts of the West," 1867, p. 48.
† H. C. Salmon. *Min. and Smelt. Mag.*, 1862, vol. ii., p. 277.
‡ J. A. Phillips. *Q.J.G.S.*, vol. xxxi., 1875, p. 324.

1,072 grains of dissolved material per gallon, principally salt and calcium carbonate.* Phillips attributes the magnesia in the rock to the action of sea water which traverses the great cross-course.

WHEAL SEYMOUR.—In the shallow parts of the lode there occurred copper and zinc.†

SILVER HILL (Perranarworthal).—There is a copper lode near the road leading to Perranarworthal. Another lode further north has yielded mundic.

SOUTH WHEAL BASSET.—*Teague's Lode* has been profitably worked for copper ores. The lode underlies north. At the 120-fathom level it varies in width from 2 to 4 feet and consists largely of quartz.

The North Lode underlies north and is 2 to 3 feet in width. This lode has a good gossan and consists of quartz and peach, with copper and tin ore.

Engine Lode.—Underlies N. 13 deg. It is a large and poor lode from the 60 to the 90-fathom level. Between 1825 and 1856 the mine yielded 94,649 tons of ore containing 7,200 tons of copper.‡

SOUTH CARN BREA MINE.—The work done in this mine is mainly upon the Great Flat lode. In this mine the *Great Flat Lode* was worked to a considerable extent about adit level, where it is in killas. The lode underlies from 35 deg. to 45 deg. S. At the 28-fathom level it underlies south 35 deg. The lode has a good gossan with vitreous and yellow copper ores and some tin. At the 128-fathom level the lode is 3 to 12 and even 18 feet in width. At the 164-fathom level (95 fathoms west of the Engine shaft) the granite was penetrated, and at this level the veinstone consisted of peach, quartz, and fluorspar. Foster states that there is a copper leader in the lode, 2 to 4 feet in width, and that the lode makes a sudden bend in one place, changing its bearing from E. 33 deg. N. to E. 15 deg. N.§ Tin and copper ores occurred in bunches in the lode. The footwall in the upper levels is very near the granite, which plunges southwards at nearly the same angle as the lode.‖

SOUTH CONDURROW MINE.—This mine is situated on the *Great Flat Lode*, which is entirely in granite in this mine. Foster states that the tin-bearing part of the lode is 5 or 6 feet in width, while the lode and capel together are 12 or even 20 feet in width. It has a general bearing of E. 34 deg. N., and underlies south at 60 deg. at the 80 or 90-fathom level. The lode is a schorl rock traversed by innumerable quartz veins, a great many of which dip north at a high angle. In many places it contains chlorite and iron pyrites with kaolin, which occasionally fills up vughs in quartz veins.¶ The *Middle Lode* varies in width from 2 to 3 feet, producing both copper and tin. The lode underlies north but is nearly vertical.

South of the middle lode is the *West Basset Copper Lode*, which varies in width from 3 to 4 feet. It splits up into branches at the 61-fathom level. At the 20-fathom level the lode yielded sulphides of copper in a veinstone of quartz, peach, and killas. At 120 fathoms west of Grenville shaft the copper lode heaves the Flat lode 10 fathoms, and Captain Hooper states that it is at this place that the Great Flat lode was first discovered.

SOUTH CRENVER.—Worked to the 94-fathom level (115 fathoms below surface).

* "Particulars of a Thermal Spring at Wheal Seton." *Miners' Assoc.*, 1873, p. 53.

† Thomas.

‡ Phillips and Darlington. "Records of Mining and Metallurgy," 1857.

§ C. Le Neve Foster, "On the Great Flat Lode." *Q.J.G.S.*, vol. xxxiv., 1878.

‖ J. Maynard, "Report on Two Cross Sections." *Rep. Corn. Poly. Soc.*, 1873, p. 191.

¶ "On the Great Flat Lode." *Q.J.G.S.*, 1878, vol. xxxiv.

South Dolcoath.—The mine was worked by the ancients. The lodes have fine gossans below which was rich copper ore.* From 1829 to 1831, 286 tons of ore containing 25 tons of copper were sold by public ticketing.†

South Wheal Frances.—The sett is traversed by five lodes which have a bearing of about E. 35 deg. N.

North or *Main Lode.*—Underlies N. 12 deg. from surface to adit level (32 fathoms from surface). From adit level to the 50-fathom level the underlie is N. 10 deg., and from the 50-fathom level downwards it is about 5 deg. N. There was a good gossan and a bunch of copper ore to the 40-fathom level. Tin ore and quartz was also present, mixed with ferruginous materials, and fluorspar, peach, chlorite, prian, &c. Below the 40-fathom level the lode is mainly tin bearing, and varies in width from 2 to 12 feet. At the 114-fathom level it is 1 to 3 feet wide, with ore bunches.

Grillis (or *St. Aubyn*) *Lode.*—The lode near Harvey's shaft is 6 feet wide and consists largely of quartz and iron with some ore. At 45 fathoms west of the shaft it is 2 feet wide and in an elvan.

South Lode.—This lode is 36 fathoms south of the main lode. It underlies south, and is about 2 feet in width.

Little's Lode.—About 2 feet in width, and consists largely of ferruginous materials.

The Great Flat Lode dips into this mine from West Wheal Basset. It was first intersected at the 185-fathom level, and has been worked upon to a considerable depth. The bearing is E. 41 deg. N., and the underlie is 58 deg. south. The ore contains about 2⅜ per cent. of black tin. The Great Flat lode is intersected by three north underlying lodes.‡

Between 1844 and 1856, 33,522 tons of ore containing 3,252 tons of copper were sold by public ticketing.§

South Wheal Hawke.—The *South Wheal Hawke Lode* yielded copper. It underlies N. 13 deg. and is intersected by a *Caunter Lode* underlying N. 5 deg. and containing copper. (Thomas.)

South Roskear Mine.—There are seven parallel lodes, but only two have been seriously worked. The *South Roskear Lode* and a lode to the north are those upon which most work has been done. Between these lodes is another called the *Boundary Lode.* The *Dolcoath North Entral Lode* enters the sett on the south. This lode yielded copper and tin ore in Dolcoath, Tincroft, South Crofty, and East Pool.

Both copper and tin ore were taken from the South Roskear lode at the 170-fathom level near Gregory's Engine shaft. The lode varied from 2 to 3 feet in width. At Vivian's shaft tin, copper, and arsenical ores were extracted between the 80 and the 112-fathom levels. Near the South Roskear (or Pendarves) shaft, copper and tin occurred at the 132-fathom level, while the Caunter lode yielded copper ore. Granite was not met with in the workings, although they extend below the 180-fathom level, nor was that rock encountered in the 143 cross-cut south. Argall states that the lode was very productive near an elvan.‖

The Copper Tankard Lode passes into this sett.

Between 1821 and 1850, 37,807 tons of ore containing 2,904 tons of copper, were sold by public ticketing. In 1841, copper ore at £5 4s. a ton realised £9,932.

South Wheal Seton. (Fig. 40.)—The *Main Lode* is 4 to 8 feet in width and contains copper, blende, and mundic, with peach, quartz, and killas veinstone.

* J. Maynard, "Remarks on Two Cross Sections." *Rep. Corn. Poly. Soc.*, 1871, p. 201.

† Phillips and Darlington. "Records of Mining and Metallurgy," 1857.

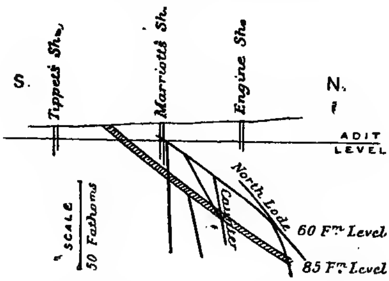
‡ Foster.

§ Phillips and Darlington. "Records of Mining and Metallurgy," 1857.

‖ W. H. Argall, "On Elvan Courses." *Miners' Assoc.*, 1875.

The North Lode underlies N. 35 deg. and varies in width from 3 to 4 feet. The lode forms a junction with the main (or Marriott's) lode at the 60-fathom level. Blende, copper ore, and galena occurred at the 50-fathom level, with quartz and killas veinstone.

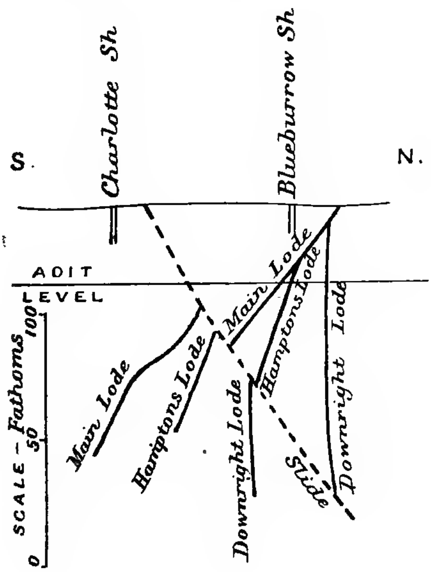
FIG. 40.—*South Wheal Seton.*



SOUTH WHEAL TOWAN. (Fig. 41.)—*Slide Lode.*—Bearing N.E. and S.W. It underlies N. 22 deg. to 35 deg., and varies in width from 7 or 8 inches to 3½ feet. It consists of earthy brown ore, quartz, and slaty clay.

At the 36-fathom level there is quartzose slate and brown iron ore and copper pyrites.

FIG. 41.—*South Wheal Towan.*



South Lode.—E. 24 deg. N., underlies S. 16 deg. to 30 deg. Varies in width from 2 to 4½ feet. It consists of earthy brown iron ore, some chlorite, and spots of copper pyrites to the 36-fathom level.

Mineral pitch occurred in both mines. (Henwood.) The mine is worked to the 114-fathom level. The shoot of ore pitched from Woolcock's shaft to

Engine shaft. 24,161 tons of copper ore containing 1,610 tons of copper were sold by South Wheal Towan and Wheal Lydia between 1817 and 1847.*

South Tresavean Mine.—The *Engine Lode* was worked for a considerable distance along the outcrop, and at adit level it varies in width up to about 3 feet, and yielded low-grade tin ore. Pitchblende with kupfernickel, native silver, and rich argentiferous galena also occurred.†

Wheal Sparnon.—*Wheal Sparnon Lode.*—Copper and tin. Underlies S. 15 deg. North of Wheal Sparnon lode is the *North Lode.* Copper and tin. Underlies N. 13 deg.

Belfry Lode (is S. of Sparnon lode). Tin. Underlies S. 45 deg. Another lode further south contains copper and underlies N. 27 deg. (Thomas.) Gold was found in a burrow and in a cross-course.‡ 1,547 tons of ore containing 128 tons of copper were sold by public ticketing between the years 1815 and 1827.§

Wheal Spinster.—The lode has been worked for tin at surface for at least 10 fathoms. No copper ore was found in the upper part of the lode.‖ 4,520 tons of ore containing 400 tons of copper were sold by public ticketing between the years 1820 and 1829.¶

Wheal Squire.—*United Mines Great Lode.*—Copper. Underlies N. 15 deg.

A lode north of this yielded tin. It underlies N. 15 deg.

Further north is *Cocks' Gossan Lode.* Copper. Underlies 10 deg. N.

Oates' Lode.—Copper. Underlies N. 5 deg.

North of Oates' lode is *Pos's Lode,* which contains copper and tin ore, and underlies N. 23 deg.

Old North Lode.—Copper. Underlies N. 23 deg.

Old South (or *Andrew's*) *Lode.*—Copper. Underlies N. 15 deg.

Wheal Lovely (or *Flat*) *Lode.*—Lode contains copper and tin, and underlies N. 45 deg.

South Flat Lode.—Copper. Underlies N. 45 deg.

Pearce's Lode.—Copper. Underlies N. 15 deg.

Another copper lode underlies N. 15 deg. (Thomas.)

Carne states that a lode in Wheal Squire underlies N. 54 deg.

20,082 tons of ore containing 1,724 tons of copper were sold by public ticketing between the years 1816 and 1853.**

Stray Park Mine.—The *Main Lode* underlies S. 14 deg., and varies in width from 2 to 10 feet. There is a good gossan in the upper part of the lode, and below this to the 124-fathom level it was very rich in copper ores. At the 15-fathom level the lode was 9 feet wide, and contained tin ore. At the 180-fathom level, where it traverses an elvan, the tin ore was rich, while the lode varies in width from 3 to 4 feet. At the 204-fathom level it is 14 feet wide, and contains good tin ore down to the 250-fathom level. The Engine shaft struck the granite at the 115-fathom level. Towards the east, at the 180-fathom level, the lode divided. The south part contained copper ore.

South Lode.—Underlie 13 deg. N. Varies in width from 1½ feet in the upper levels to 5 feet at the 250-fathom level. At the 180-fathom level it is 2 fathoms south of the main lode. The lode was rich in copper ore from the 80 to the 160-fathom level, below which it yielded mainly tin ores.

* Phillips and Darlington. "Records of Mining and Metallurgy," 1857.

† R. Pearce, "Note on Pitchblende in Cornwall," *Tr. R.G.S. Corn.*, vol ix., 1864 to 1878, p. 102.

‡ J. Garby, "Notice of the Occurrence of Gold in a Cross-Course." *Tr. R.G.S. Corn.*, 1846, vol. vi., p. 265.

§ Phillips and Darlington. "Records of Mining and Metallurgy," 1857.

‖ W. H. Argall. Miners' Assoc. (Breage Meeting), 1872.

¶ Phillips and Darlington. "Records of Mining and Metallurgy," 1857.

** *Op. cit.*

There are three lodes north of the main lode, which were intersected by a cross-cut at the 100-fathom level.

The first is 28 fathoms north of the main lode. It is 1½ feet in width and underlies N. 20 deg. This lode yielded copper and tin ore. The second is 45 fathoms north of the main lode. It is a poor lode, with a northerly underlie, and about 1 foot in width. The third lode is 67 fathoms north of the main lode. It underlies N. 10 deg., and contains copper ore with quartz.

Between the years 1829 and 1856, 38,610 tons of ore containing 2,748 tons of copper were sold by public ticketing. In 1841, copper ore sold at £6 3s. a ton realised £5,972.

Swanpool Mine.—This mine was worked at about the same time as Wheal Clinton. In 1855 it was down to 80-fathom level, four shafts having been sunk on the lode. At the 20-fathom level the lode is in one place 9 feet wide, and consisted of flucan with gossan, and rich bunches of galena yielding 1½ to 2 tons of lead ore per fathom. At the 40-fathom level the lode is 2 feet wide and consists of gossan, flucan, mundic, and large stones of mixed blende and lead ore. At the 80-fathom level it is 2 feet wide, and consists of quartz, mundic, and flucan, with good branches of galena. The lode underlies south.* Silver and a little gold also is said to have occurred in the lode.† On the eastern side of Swanpool Lake are three levels driven on three lodes. Several shoots of lead were passed through, especially in the *Middle Lode*, which is 20 inches in width and composed of flucan, quartz, and galena.‡

Wheal Tehidy.—There are some ancient workings on the upper parts of the lodes, but the mine was first seriously worked in 1835.

North or Tin Lode.—Underlie 35 deg. N. The lode varies in width from 1 to 3 feet. It is a continuation of the East Pool or Tincroft North lode. It contained copper and blende as well as quartz and flucan.

Caunter Lode.—This lode has an irregular underlie northwards. It varies in width from 1 to 2 feet from adit to the 70-fathom level and yielded copper ore and mundic in a quartzose veinstone.

2,121 tons of ore containing 179 tons of copper were sold by public ticketing between the years 1835 and 1856.§

Ting Tang Mine.—*Main Lode.*—E. 12 deg. N. Underlies N. 8 deg. to 30 deg. The lode contained copper pyrites, earthy brown iron ore, black and vitreous copper ore. At the 80-fathom level there was some chrysocolla with black copper and copper pyrites. At the 90-fathom level there was oxide of copper. At the 140-fathom level there was blue and green copper carbonate with chlorite, and quartz.

Middle Lode.—E. 21 deg. N. Underlies N. 4 deg. to 22 deg. and varies from 1 to 4 feet in width. It contained earthy brown iron ore, vitreous and black copper ore, and red crystallised oxide of copper at the 90-fathom level. At the 140-fathom level there was granular quartz, chlorite, and vitreous copper.

Roche's Lode.—E. 8 deg. S. Underlies N. 10 deg. to 22 deg. Varies in width from 1½ to 3 feet and contains quartz, chlorite, iron and copper pyrites, earthy red iron, and vitreous and black copper ore from 90 to the 120-fathom level. (Henwood.)

Thomas states that there is a *Flat Lode* in this mine which yielded both copper and tin. It is the continuation of Wheal Lovely and Wheal Squire lode, and underlies N. 45 deg. Seven fathoms south of the Flat lode is a *Mundic Lode* (which is the South Flat lode of Wheal Squire) underlying N. 45 deg. Between 1816 and 1835, 38,124 tons of ore containing 3,235

* F. J. Stephens, "Mineral Resources of Falmouth." *Rep. Corn. Poly. Soc.*, 1886, p. 189.

† F. J. Stephens, "Recent Discoveries of Gold in West Cornwall." *Tr. R. G. S. Corn.*, 1899.

‡ F. J. Stephens, "Mineral Resources of Falmouth." *Rep. Corn. Poly. Soc.*, 1886, p. 189.

§ Phillips and Darlington. "Records of Mining and Metallurgy," 1857.

tons of copper were sold by public ticketing, and 841 tons containing 50 tons of copper between 1845 and 1847.*

TOLCARN.—*North Lode.*—Copper. Underlies N. 15 deg. (South lode in Wheal Jewell).
South Lode.—Copper. Underlies N. 15 deg.

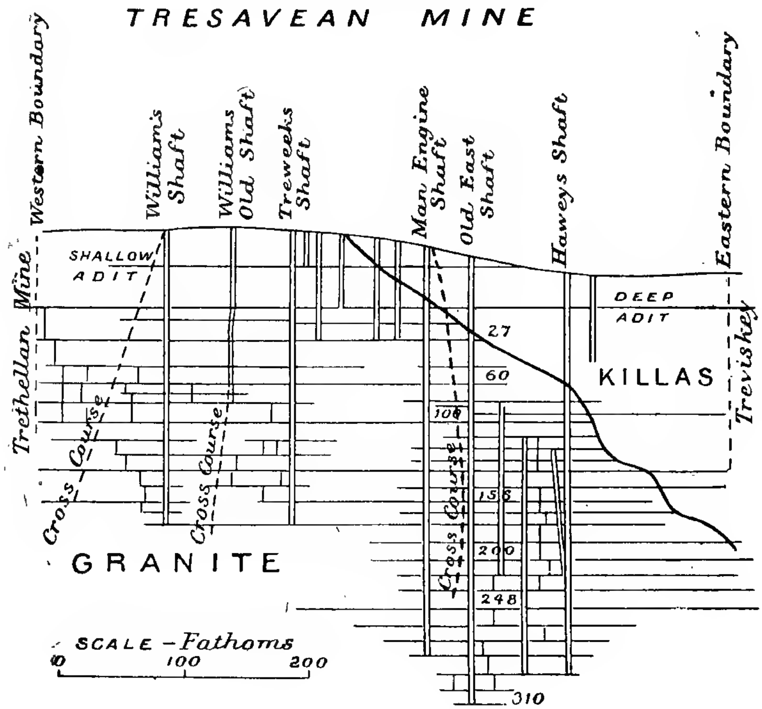
TREFULA MINE.—*Trefula Lode.*—Copper. Vertical. (Thomas.)

TRELEIGH CONSOLS (GOOD SUCCESS) MINE.—*Good Success or John's Gossan Lode.*—(Copper). Underlies N. 23 deg.
North Good Success Lode is situated 60 fathoms further north. It is a copper lode underlying N. 23 deg.
Between 1833 and 1855, 21,904 tons of ore containing 1,420 tons of copper were sold by public ticketing.†

TREMENHEERE MINE.—Worked to the 204-fathom level.

TRESAVEAN MINE. (Fig. 42.)—The *Main Lode* bears E. 30 deg. N., and underlies S. 6 deg. to 30 deg. down to the 276-fathom level. It varies in width from 1 to 10 feet, being widest at the 206-fathom level. It consists of quartz, earthy brown ore, black copper, and copper and iron

FIG. 42.—*Tresavean Mine.*



pyrites. There was quartz and schorl at the 264-fathom level. At the 228-fathom level the lode was very rich in copper sulphide. Mr. Collins has described blue peach from this mine, and remarks that it is a slightly stanniferous capel showing a "shadowy granitic structure."‡

* Phillips and Darlington, "Records of Mining and Metallurgy," 1857.
† *Op. cit.*
‡ *Min. Mag.*, vol. iv., 1882, p. 13. "Cornish Tinstones and Capels."

Thomas states that there are four lodes all of which have yielded copper. They underlie south.

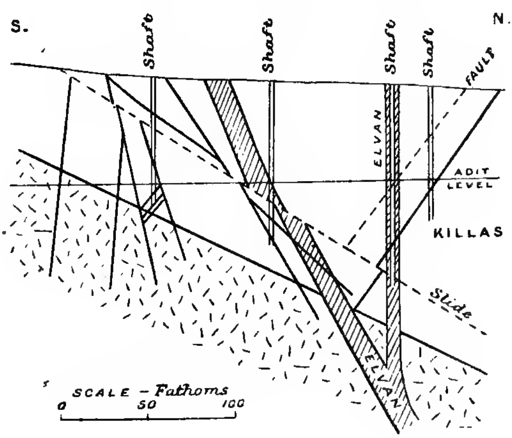
Between 1815 and 1856, 163,259 tons of ore containing 15,702 tons of copper were sold by public ticketing.*

WHEAL TOWAN.—*Great Lode.*—E. 20 deg. N. Underlies S. 8 deg. to 28 deg. From the 36 to the 142-fathom level the lode varies in width from 3 inches to 12 feet. In the upper levels the lode consists of earthy brown iron ore, iron pyrites, quartz, chlorite, tin ore, and copper pyrites and some blende. In the deeper levels the lode contains copper and iron pyrites and quartz coated with carbonate of iron. (Henwood.)

Between 1815 and 1835, 26,058 tons of ore containing 1,465 tons of copper were sold by public ticketing.†

TRESKERBY MINE. (Fig. 43.)—*Old South Lode.*—Copper. Underlies S. 15 deg. (continuation of William's lode in Chacewater Mine).

FIG. 43.—*Treskerby Mine.*



North Lode.—Copper. Underlie N. 10 deg. (a branch of the old South lode).

Middle Lode.—Branch of the old South lode. It underlies north and falls into the North lode.

Wheal Vor Lode.—Tin. Underlies S. 27 deg. It is called Prussia lode in Wheal Boys and Butter's lode in Wheal Harmony.

Chacewater or William's Lode.—Copper. Underlies N. 40 deg. for 50 fathoms in depth and then underlies N. 27 deg.

William's South Lode.—Copper. Underlies N. 28 deg.

Teague's Lode.—Copper. Underlies S. 23 deg.

Flat Lode.—Copper. Underlies N. 40 deg., crosses the Chacewater lode at the 70-fathom level.

Carquean North Lode.—Copper. Underlies N. 15 deg.

Carquean South Lode.—Copper. Underlies N. 5 deg. (Thomas.) Phillips and Darlington state that between the years 1815 and 1832 only 6 tons of copper ore were sold at public ticketing.

TREVENEN MINE.—Carne states that the lodes were richest at a depth of 150 fathoms from surface.‡

TREWAN MINE.—*Trewan North Lode.*—Copper. Underlies S. 15 deg. (It is the Briggan lode.)

* Phillips and Darlington, "Records of Mining and Metallurgy," 1857.
† *Op. cit.* ‡ p. 90.

Trewan South Lode.—Underlies S. 23 deg. Between these lodes is a tin lode underlying N. 27 deg.

TREWIRGIE DOWNS.—*North Lode.*—Contains copper. It underlies N. 7 deg.

The *South Lode* contains copper and underlies N. 7 deg. (Thomas.)

WHEAL TRUMPET.—*Wheal Trumpet Lode.*—(Westerly continuation of Wheal Ann lode.) Bearing E. 22 deg. N. Varies in width from 4 inches to 1 foot. Underlies N. 6 deg. to 24 deg. From 73 to 117-fathom level it contains earthy brown iron ore and cassiterite.

At 157-fathom level the granite is friable and the lode contains quartz. (Henwood.)

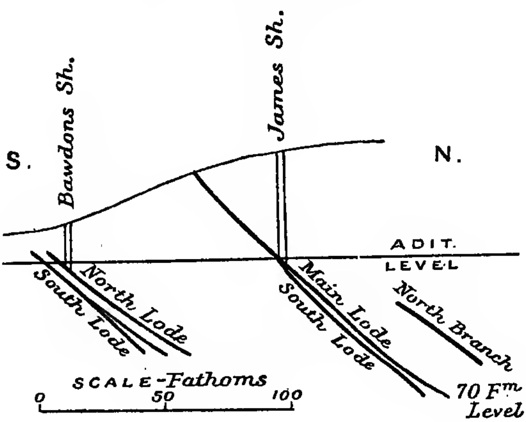
UNION, WHEAL.—*Wheal Union Lode.*—Tin and copper. Underlies N. 32 deg.

Grove Lode is situated north of Wheal Union lode. It contains tin, and underlies N. 32 deg. (Thomas.)

In 1838, 101 tons of copper ore containing 6 tons of copper were sold by public ticketing.*

UNITED HILLS. (Fig. 44.)—Lode strikes E. 26 deg. N. Underlies N. 42 deg. to 60 deg. It varies in width from 4 inches to 7 feet to the 52-fathom

FIG. 44.—*United Hills.*



level, and consists of quartz, quartzose slate, copper and iron pyrites enclosing irregular masses of slate. (Henwood.)

Between 1826 and 1847, 54,473 tons of ore containing 3,582 tons of copper were sold by public ticketing.†

Within the Tywarnhaile sett the lode has been worked upon for a distance of 400 fathoms. The width of the lode is very irregular, and the ore occurred in hard quartz, slate, or capel. At the 50-fathom level east of Bennett's shaft a cross-cut was driven south to intersect a Caunter and the Wheal Charles lode. The Caunter lode at the 80-fathom level was 2 feet wide and contained zincblende and iron pyrites.

UNITED MINES.—*Old Lode.*—E. 27 deg. N. 2 to 8 feet in width. Underlies N. 6 deg. to 30 deg. It consists of quartz, slate, clay, earthy brown iron ore, black copper ore, and copper pyrites. At the 128-fathom level there was granular quartz, slate, zincblende, copper pyrites.

* Phillips and Darlington. "Records of Mining and Metallurgy," 1857.
† *Op. cit.*

At the 92-fathom level there was a branch bearing E. 20 deg. N. about 2 feet wide and underlying S. 10 deg. to 20 deg. It contained quartz, slate, and copper pyrites.

Another at the same level is 4 inches wide, and underlies S. 50 deg. to 60 deg., and consists of quartz, slate, and some copper and iron pyrites.

Middle Lode.—E. 30 deg. N. Lode vertical, and quartzose. Varies in width from 2 to 3 feet.

Michell's Lode.—E. 25 deg. N. Underlies S. 8 deg. to 20 deg., is 4 or 6 inches in width, and consists of quartz and slate.

A branch of Michell's lode bears E. 20 deg. N., and underlies S. 6 deg. to 20 deg. It is 3 inches in width and consists of quartz, slate, and copper pyrites.

Mundic or *Buzzas Lode.*—E. 25 deg. N. Varies in width from a few inches to 4 feet. Underlies N. 12 deg. to 30 deg. Contains copper pyrites, quartz, and slate to 148-fathom level.

Bawden's South Lode.—E. and W. Underlies S. 10 deg. to 24 deg. It is 3 inches to 3 feet in width. At the 148-fathom level it is composed of quartz, copper, and iron pyrites.

Bawden's North Lode.—E. 22 deg. N. Underlies S. 17 deg. to 30 deg. It is 1½ to 3 feet in width. It contains copper pyrites and quartz.

Nicholls' Branch.—E. and W. Underlies S. 12 deg. to 30 deg., and varies from 1 to 3 feet in width. Contains copper pyrites and quartz at 98-fathom level.

Polkinhorne's Lode.—E. 15 deg. S. Underlies N 14 deg. to 25 deg. It is 2 feet in width and consists of quartz, slate, and schorl at 92-fathom level.

A Branch of Polkinhorne's Lode bears E. 20 deg. N. and underlies S. 16 deg. to 30 deg. It consists of quartz, slàte, and schorl rock.

Gellard's North Lode.—E. 28 deg. N. Varies from 1 to 4 feet in width and underlies S. 16 deg. to 22 deg. from the 46 to the 54-fathom level. It contains quartz, felspar, black copper, and copper pyrites.

Gellard's South Lode.—E. 20 deg. N. at the 46-fathom level. The lode underlies S. 16 deg. to 28 deg. and varies in width from 1½ to 2 feet. It contains copper pyrites, black copper, quartz, and slate.

Mellet's Lode.—E. 30 deg. N. Underlies N. 10 deg. to S. 20 deg., and varies in width from 1 to 3 feet. Consists of quartz, slate, and copper pyrites.

Great South Lode.—E. 30 deg. N. (in the Ale and Cakes part). From the 163 to the 213-fathom level the underlie is N. 16 deg. to N. 40 deg. It varies in width from a few inches to 8 feet, and consists of quartz, copper pyrites, barytes, &c. The ore shoots pitch eastwards. (Henwood.)

Thomas has recorded a few particulars regarding the numerous lodes of the United Mines, but has called the lodes by different names from those which Henwood gives them.

Between 1815 and 1856, 304,528 tons of ore containing 22,681 tons of copper were sold by public auction.* (See Consolidated Mines.)

WHEAL UNITY. (Figs. 45 and 46.)—*Wheal Unity Lode.*—Copper. Underlie N. 25 deg. The lode was worked in Wheal Gorland.

North Lode.—Copper. Underlies N. 27 deg. Branches off from Unity lode and then rejoins it.

South Lode.—Copper. Underlies N. 10 deg.

Francis Lode.—Copper. Underlies S. 15 deg.

Wheal Solid Lode.—Tin. Underlies S. 10 deg. Frances and Wheal Solid lode unite in depth.

Barrett's Lode.—Copper. Underlies S. 10 deg.

Cain's North Lode.—Copper and tin. Underlies N. 30 deg.

Cain's South Lode.—Copper. Underlies N. 10 deg.

Trefusis Lode.—Tin and copper. Underlies N. 13. This lode is the most southerly in the sett. North of it is *Blamey's Lode*, which consists largely of elvan in which tin ore occurs. It underlies N. 10 deg.

Peter's Lode.—Copper. Underlies N. 23 deg. (Thomas.)

* Phillips and Darlington, "Records of Mining and Metallurgy," 1857.

108,698 tons of ore containing 8,836 tons of copper were sold by public auction from Wheal Unity and Poldice between 1815 and 1849.*

WHEAL UNITY WOOD.—*Pits an Vollar Lode.*—E. 30 deg. N. From 30 to 80-fathom level, the lode underlies N. 16 deg. to N. 30 deg., and varies in width from ½ to 3 feet. It consists of quartz, chlorite, fluorspar, iron and copper pyrites.

Little Ore Lode.—E. 30 deg. N. Underlies N. 30 deg. to 38 deg., and is about 6 inches wide. It consists of quartz and slaty clay.

FIG. 45.—*Killifreth. Unity Wood.*

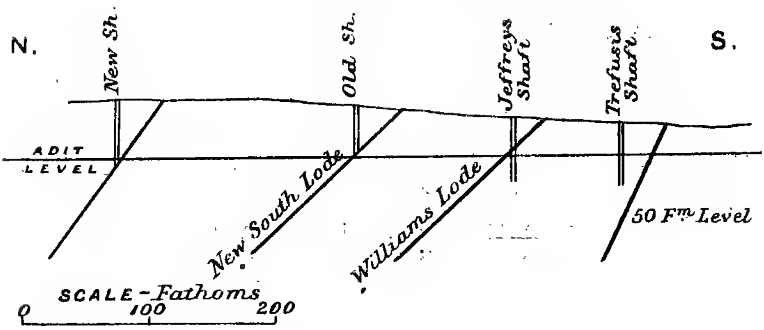
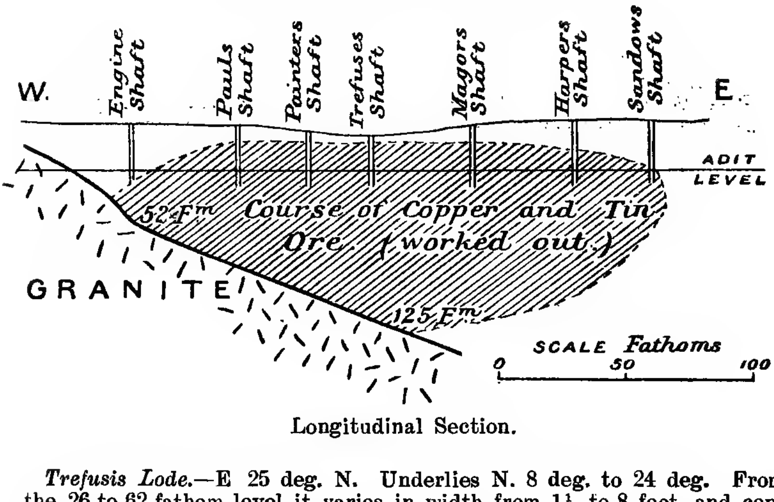


FIG. 46.—*West Poldice. Unity Wood.*



Longitudinal Section.

Trefusis Lode.—E 25 deg. N. Underlies N. 8 deg. to 24 deg. From the 26 to 62-fathom level it varies in width from 1½ to 8 feet, and consists of quartz, copper pyrites, chlorite, and slaty clay with fluorspar and iron pyrites.

Great Elvan Lode.—E. 30 deg. N. Underlies N. 45 deg. to 50 deg. It is 4 fathoms in width, and contains large quantities of tin sprinkled through it.

Trestrail's Elvan.—E. 30 deg. N. Underlies N. 10 deg. and varies in width from 1 foot to 2 fathoms. It is a fine-grained schorl rock with felspar. There were large quantities of tin above a slide. (Henwood.)

* Phillips and Darlington, "Records of Mining and Metallurgy," 1857.

Between 1827 and 1842, 32,756 tons of ore containing 2,465 tons of copper were sold by public auction.*

Wheal Uny.—The *Great Flat Lode* strikes E. 22 deg. N., but westwards the strike is E. 37 deg. N. The general underlie is 44 deg. The lode is wrought for a distance of 300 fathoms in the direction of strike. It lies very near the junction of the granite and killas but is mainly enclosed in granite.† The lode from the 190 to the 200-fathom level is practically vertical at Hind's shaft. The average width of the lode is 10 feet, but it is as narrow as 4 feet in some places, as at the 180-fathom level on the east of the Engine shaft. It contains 56 to 70 lbs. of black tin per ton of ore, the percentage of black tin diminishing where the lode is wide. The shoots of tin pitch eastwards. Hind's shaft is sunk to the 214-fathom level. King's shaft is sunk to the 160-fathom level. At the 190-fathom level several tons of rich copper pyrites were broken in the lode in 1884.‡

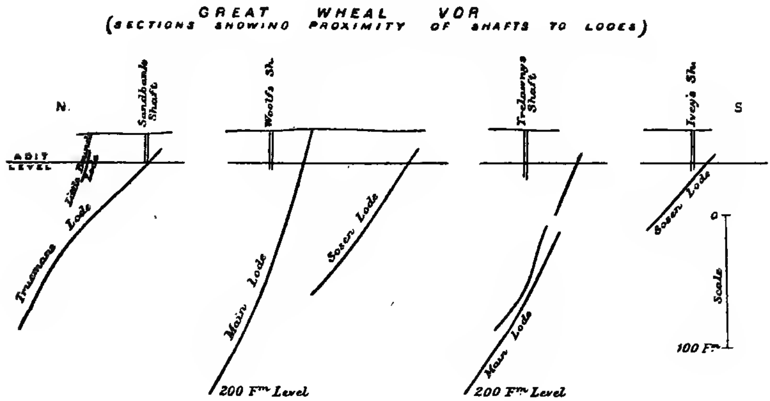
Between 1826 and 1856, 755 tons of ore containing 39 tons of copper were sold by auction.§

Wheal Virgin.—*Wheal Virgin Lode.*—Copper. Underlies N. 16 deg.
Terrill's Lode.—Copper. Underlies S. 13 deg.
Cross Cut Lode.—Copper. Underlies S. 13 deg.
Tregonning's Lode.—Copper. Underlies S. 13 deg.
South Lode.—Copper. Underlies N. 15 deg.

Between Tregonning's and South lode there is a tin lode underlying N. 50 deg. There is elvan on the south wall and killas on the north wall. North of the South lode is a copper lode underlying N. 10 deg. (Thomas.)

Between 1841 and 1847, 22,974 tons of ore containing 1,656 tons of copper were sold by auction.‖

Fig. 47.

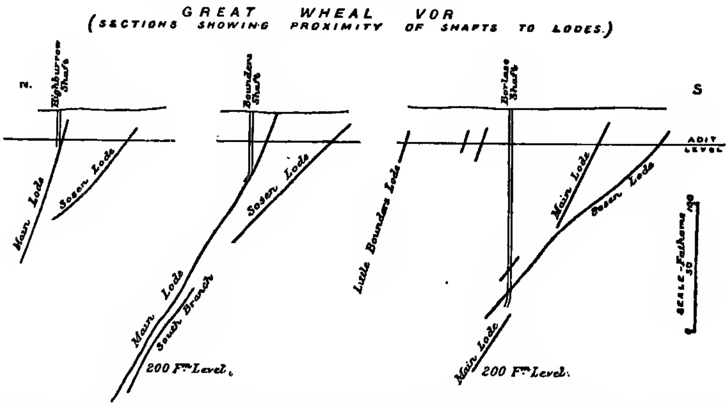


Wheal Vor. (Figs. 47 to 51.)—The *Metal Lode* bears E. 10 deg. to 15 deg. N., and underlies 10 deg. to 25 deg. N. Wood-tin was found in the lode about the year 1867 at 180 fathoms from surface, on the west of the Metal shaft. About 1873, similar ore was found 80 fathoms

* Phillips and Darlington, "Records of Mining and Metallurgy," 1857.
† Foster, p. 640.
‡ R. H. Thomas, "Some Observations on the Great Flat Lode in Wheal Uny." *Rep. Corn. Poly. Soc.*, 1886, p. 184.
§ Phillips and Darlington, "Records of Mining and Metallurgy," 1857.
‖ *Op. cit.*

further east in the same lode, which is about 2 feet in width. At this level the lode widened out rather suddenly, while the veinstone became more chloritic, less quartzose, and contained a large amount of tin, either in separate segregations or mixed with the veinstone. Wood-tin occurs either in scattered grains, in small isolated masses, or in veins of varying and inconsiderable width, sometimes as thin

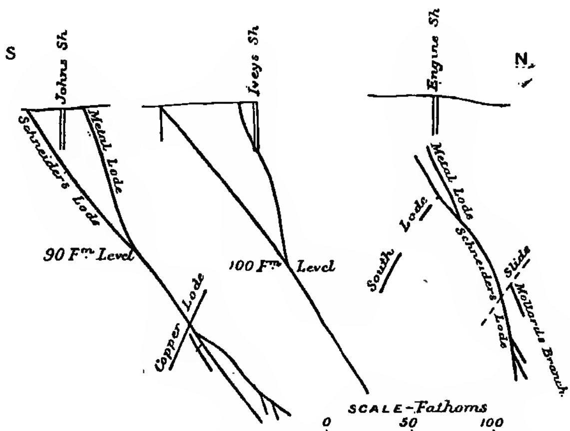
FIG. 48.



as paper, but it is always in a fibrous condition. Some of the masses exhibit concentric structure, of clove brown and brownish yellow laminæ, but the structure is radiately crystalline. These aggregations of divergent crystals sometimes enclose kernels of ordinary tin ore that radiate from minute cavities.*

At the 162-fathom level, wood-tin occurred in large kidney-shaped masses associated with crystalline cassiterite and quartz in part of the Wheal

FIG. 49.—*Sithney Wheal Metal.*



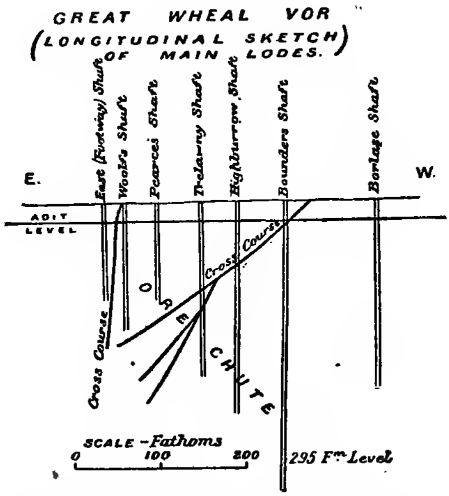
Metal lode. The lode was 6 feet in width, and worth £600 per cubic fathom. The wood-tin occurred intermixed with ordinary crystalline tin-

* W. H. Argall, "On the Occurrence of Wood-tin in the Wheal Metal Lode at Wheal Vor." *Journ. Roy. Inst. Cornwall*, vol. iv., 1873, p. 255.

stone, together with much chlorite, chalcedony, dolomite, felspar, and pyrites.*

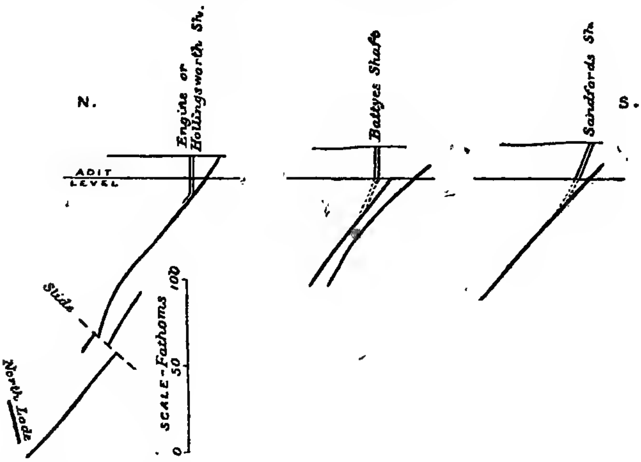
Charles Thomas, writing in 1867, remarks that for some time the returns of tin ore were 200 tons a month, yielding 150 tons of fine tin. In many

FIG. 50.



places the lode was worth £1,000 a cubic fathom. It was rich to the 300-fathom level, and then became poor.† Before 1870, it is stated to have yielded over £3,000,000 worth of tin and copper.‡

FIG. 51.—*Penhale Wheal Vor.*



Henwood records the following particulars of the lodes of Great Wheal Vor:—

* J. H. Collins, "Cornish Tin Stones and Capels." *Min. Mag.*, vol. iv., 1882, p. 7.

† *Mining Fields of the West*, 1867, p. 24.

‡ R. Hancock, "On the Mineral Deposits of the Old Wheal Vor," *Roy. Corn. Poly. Soc.*, 1870, p. 101.

The *Main Lode*, in the Carleen or eastern part of the mine, bears E. 28 deg. N., and underlies N. 10 deg. to 25 deg. It varies in width from a few inches to 1½ feet, and consists of chlorite, quartz, slate, cassiterite, and iron pyrites at the 55-fathom level. At the 125-fathom level there was some arsenical pyrites with chlorite and cassiterite. The main lode in the Wheal Vor and Wheal Vrea (or eastern) part varies in width from 3½ feet to 20 feet, being widest at the 140-fathom level. At the 85-fathom level there was copper pyrites and black copper ore. At the 121-fathom level the quartzose slate was traversed by strings of cassiterite. At the 131-fathom level there is a bed of quartzose slate extending 10 feet from the lode on the north side. At the 140-fathom level a similar bed extends to 20 feet from the lode. The lode consists of quartzose slate, cassiterite, quartz strings, and drusy quartz cavities lined with crystals. At the 240-fathom level there was cassiterite, iron pyrites, and felspar. It was worked to the 285-fathom level at Bounder's shaft.

Wheal Sozen Lode.—Bears E. 24 deg. N., and underlies N. 20 deg. to 36 deg. At the 40-fathom level there was earthy brown ore and quantities of cassiterite. The lode at the 100-fathom level consists of quartz, chlorite, and slate. At the 70-fathom level there is a bed of quartzose slate traversed by quartz veins.

Carne* states that there are two elvans in the eastern part of the mine. The largest is on the north, and is 24 feet wide, bears N.E. and S.W., and underlies N. 56 deg. The lode was about 2 feet wide in killas, but in elvan was 5 feet, and in some places was so broken up into branches as to make the whole elvan for 20 feet worth working. Henwood† states that there are two elvans. The northern one is 2 feet wide, and underlies 20 deg. to 30 deg. N. The southern is 8 fathoms in width, and underlies 40 deg. to 50 deg. N. The lode was productive in both elvans. In the southern one the tin ore occurred in a somewhat sprinkled manner. In elvan the tin ore occurred either in unconnected masses and irregular bodies or as short veins. "Floors" containing tin ore strike off in a nearly horizontal direction into the killas, and are similar in composition to the lode.

The fact that the lodes only yielded tin ore while in killas and became poor on entering the granite is a well-known peculiarity of the district. Between 1821 and 1842, 4,296 tons of ore containing 330 tons of copper were sold by public auction.‡ A company has recently been promoted to re-work the mine in view of the demand for tin.

WENDRON UNITED MINES.—The *Engine Lode.*—At Engine shaft it is in granite at the 35-fathom level. It varies in width, down to that level, from 2½ feet to 4 feet. At the 60-fathom level the lode is 4 feet to 6 feet wide. The lode was a fair one, and good bunches of tin ore were found at the 35-fathom level.

Flanders Lode.— Width of lode is 1 foot to 3 feet. The granite was encountered below the 86-fathom level. A poor to fair tin lode.

Liddecoat's Lode.—This crosses the Flanders lode at 10 fathoms west of Hill's shaft. Varies in width from 3 feet to 4 feet. The veinstone is chloritic. The junction of Flanders and Liddecoat's lode was productive of tin ore.

Liddecoat's North Part.—At the 70-fathom level it varies in width from 1½ feet to 2 feet and contains fair tin ore.

Richard's Lode.—At the 20-fathom level it is 2 feet to 3 feet in width.

Wheal Fat Lode.—At the 35-fathom level the lode is 4 feet to 5 feet in width, with low-grade tin ore.

WEST CONDURROW. (Fig. 52.)—There are six lodes in this sett.

Kellivose shaft is on a lode which at adit level yielded tin and copper ores. In width the lode is from 1 foot to 5 feet.

At 22 fathoms south of Kellivose lode there is another, varying in width from 6 inches to 18 inches, which yields tin ore.

At 60 fathoms further south there is a lode yielding tin ore.

At 45 fathoms south of the last there is another known as the *Bounty North Lode.*

* "On Elvan Courses." *Tr. R. G.S. Corn.*, 1818, vol. i., p. 103.

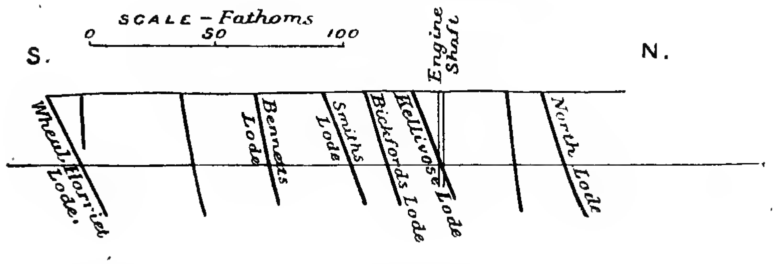
† p. 52.

‡ Phillips and Darlington. "Records of Mining and Metallurgy," 1857.

At 14 fathoms further south is the *Bounty Lode*, varying in width from 1 foot to 2 feet. This lode has a good gossan, and yielded tin ore.

The Kellivose Lode.—Bearing E. 35 deg. N., and underlies N. 27 deg. The lode has a good gossan and consists of quartz and killas with tin and copper ore. At the adit level alternations of slate, clay, and granite were met with near the shaft (Park shaft). At Purser's shaft the lode yielded tin

FIG. 52.—*West Condurrow.*



and copper and there was much flucan. At the 12-fathom level in the same shaft it is 3 feet to 3½ feet wide, and consists of quartz, prian, and killas, with bunches of copper and tin ore. At the 24-fathom level the lodestuff is quartz and peach in granite.

North Lode.—Greenstone was met with when sinking operations were commenced on this lode.*

West Wheal Damsel.—*Tremayne's Lode* has been worked upon down to the 150-fathom level. Thirty fathoms north of Tremayne's lode is the *Wheal Damsel North Lode*, which is about 1½ feet wide and yielded copper ores.

The *New North Lode* is opened up as far as the 90-fathom level.

Darlington's Lode intersects Tremayne's lode in depth, producing tin ore in the deep levels.

6,392 tons of ore containing 378 tons of copper were sold by public auction between 1852 and 1856.†

West Dolcoath.—The *Main Lode* is situated below an elvan. At adit level the width of the lode is about 2 feet. The veinstone consists of quartz, chlorite, flucan with mundic, and black and yellow copper ores. It is supposed to be a continuation of the Dolcoath main lode.

West Frances.—Smith's, or the New, shaft is sunk on the *Great Flat Lode* to the 174-fathom level. The lode consists of peach, quartz, and tin ore. Near a cross-course the lode is large, and contains a little tin ore throughout. Foster states that it has similar characteristics to those of the same lode in West Basset Mine, except that the leader, instead of being a mere joint, is a quartz vein 2 or more feet in width. The stanniferous part of the lode is under the leader, and the underlie of the lode in this mine is from 40 deg. to 53 deg. south, varying within these limits in the short distance of 80 fathoms.‡

West Wheal Jane.—Worked to the 70-fathom level at Clemow's shaft.

West Wheal Seton.—There are several lodes, but they are mainly branches of the main lode. The lodes contained blende and copper to below the 100-fathom level, and yielded tin ore below that horizon.

Old North or Main Lode.—Underlie N. 30 deg. The lode is associated with an elvan, and appears to have been richest in its immediate vicinity. It varies in width from 1½ feet to 3 feet in the upper levels, where it was not particularly rich in copper ore. Below the 120-fathom level the lode is 3 feet to 5 feet or even 10 feet in width, and yielded both tin and copper

* Information obtained from the Pendarves Estate Office through the courtesy of Mr. Vercoe.

† Phillips and Darlington. "Records of Mining and Metallurgy," 1857.

‡ Foster.

ore. It was rich at the 226-fathom level, at which place it is only 5 feet distant from elvan. The ore ground as a whole pitches west with the junction of the lode and elvan, but there was another good ore bunch near Mitchell's shaft, where the veinstone was a dark chlorite with quartz and fluorspar. At the 275-fathom level the lode was productive in tin ore. In some levels, particularly in the higher horizons, it yielded blende and mundic.

North Part.—The old North lode branched at the western Engine shaft, where the north part was 4 feet wide, and at the 20-fathom level consisted of a soft killas veinstone with blende and mundic. At the 110-fathom level the lode is 2 feet to 3 feet wide.

South Part.—At the 112-fathom level the lode is 6 feet wide in some places.

North Lode.—This lode is a branch of the old North lode at the 70-fathom level, near Harvey's shaft, on the underlie side of the lode, 2 feet wide with copper ore.

South Lode.—This is a branch of the old North lode. From the 100-fathom to the 130-fathom level the lode is 4 feet to 7 feet in width, and contains tin and copper with flucan, quartz, and mundic.

New South Lode.—Nearly vertical, but has a slight northerly underlie. Between 1848 and 1856, 14,766 tons of ore containing 989 tons of copper were sold by public auction.*

WEST WHEAL TOWAN.—The lead lode as seen in the cliff at adit level is 2 feet wide. It yielded lead and tin ore with mundic.

Hampton's Lode.—From the 25-fathom to the 43-fathom level the lode is 1 foot 3 inches wide, and contains a little tin ore.

Middleworks' Lode.—Underlies south 20 deg., and is about 2½ feet wide.

Goad's Lode.—This lode branches off downwards from the Middleworks' lode at an angle of about 10 deg. S.

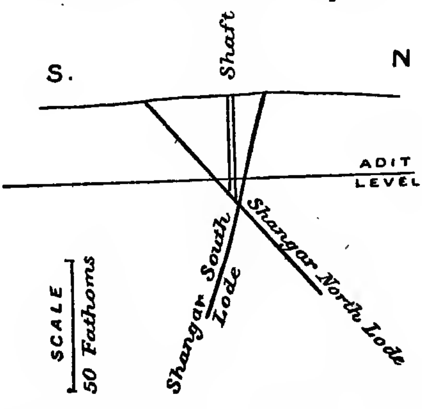
WEST WHEAL VIRGIN.—*Wheal Virgin Lode.*—Copper. Underlies N. 15 deg. It is intersected by *Wheal Maid Lode*. (Thomas.)

Carne† states that the *Great Caple Lode* is called a tin lode, and is traversed by *Tregonning's Copper Lode*, but that in depth the lode was poor in tin ore and became copper bearing. The *Main Lode* is 9 feet wide in some places, but it is on an average about 3 feet.

In Tiddy's cross-course (Consolidated Mines) vitreous copper ore and red oxide of copper with native copper were found in a few rich bunches.‡

Miscellaneous Diagrammatic Sections of Mines.

FIG. 53.—*Wheal Christopher.*



* "Phillips and Darlington. "Records of Mining and Metallurgy," 1857.
† p. 96.
‡ Henwood, p. 92.

FIG. 54.—*Cliff Down Mine.*

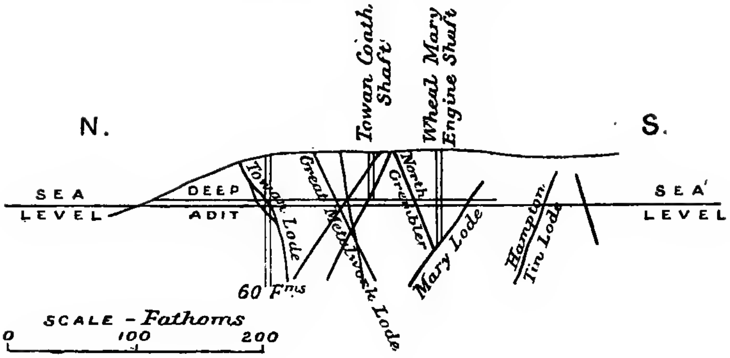


FIG. 55.—*Cliff Down Mine. Section in Valley.*

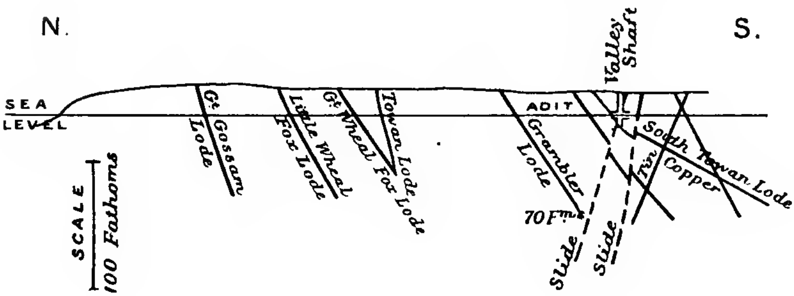


FIG. 56.—*Clyjah and Wentworth.*

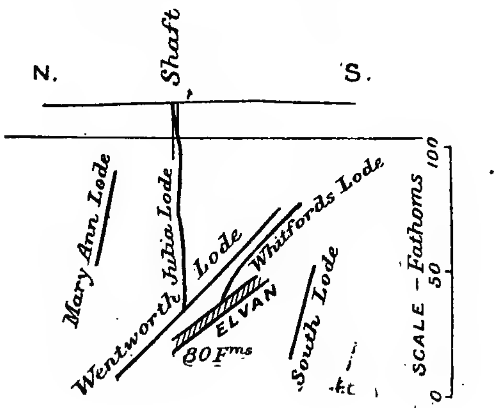


FIG. 57.—*Wheal Wentworth.*

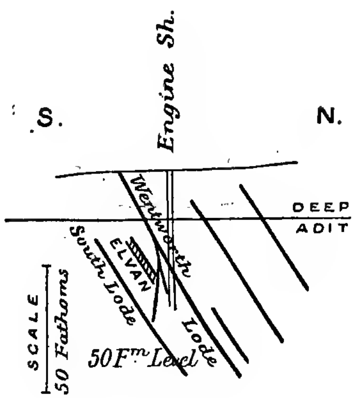


FIG. 58.—*Medlyn Moor Mine.*

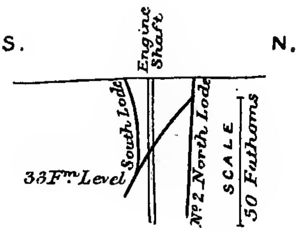
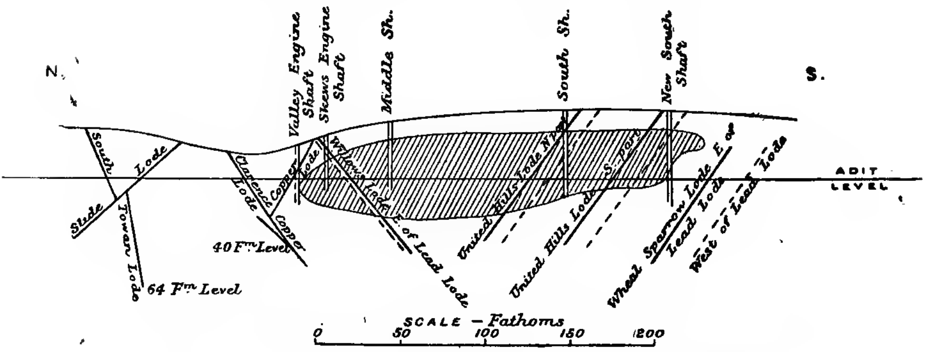


FIG. 59.—*Nancekuke Mines (Wheal Clarence).*



Longitudinal Section of Lead Lode, showing Cross Sections of Lodes Intersected by it.

FIG. 60.—*North Pool Mine.*

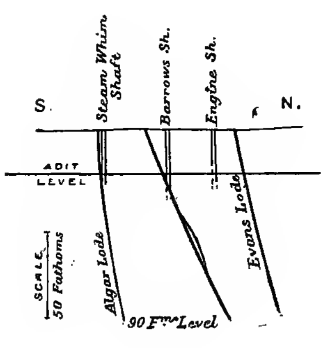


FIG. 61.—*North Wheal Vor.*

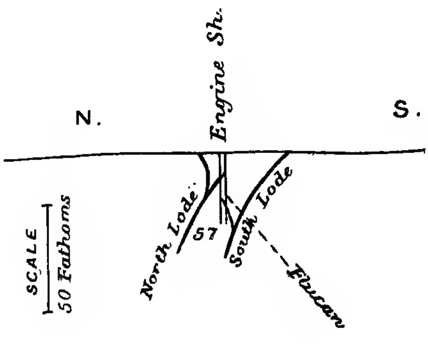


FIG. 62.—*Polrose Mine.*

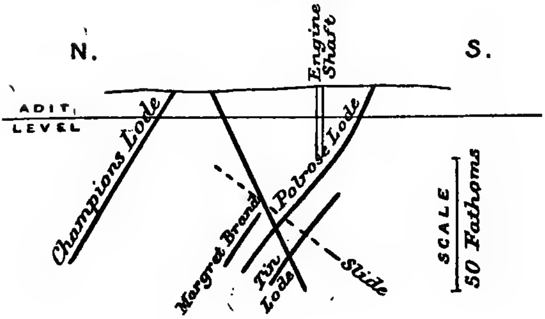


FIG. 63.—*South Lovell Mine.*

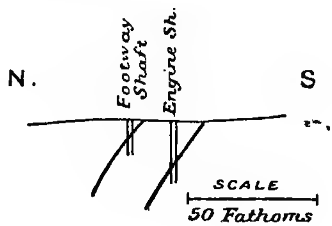
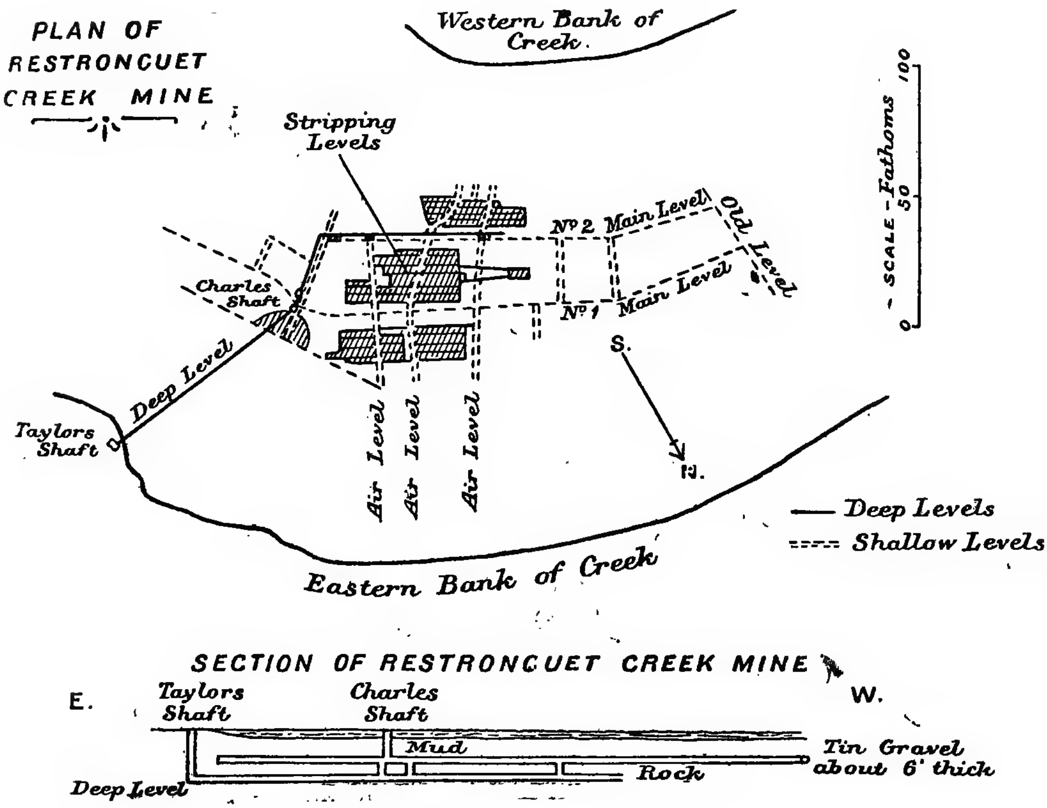


FIG. 64.



CHAPTER XVIII.

MINING ECONOMICS.

INTRODUCTORY REMARKS.

This area embraces the most important mining district in Cornwall, and although in late years mining has declined in the region owing to foreign competition and the consequent depreciation in value of the ores for which the area is so celebrated, it is still justly famous for its ancient historical connections, its mineral wealth, and the geological problems which it presents. The abundance of the metalliferous minerals encountered in mining operations early attracted the attention of man, and in more recent times the variety of its mineral products has afforded a fascinating field for study to observers in the various branches of the science. As a field for economic enterprise it once held a premier position, and could the history of the financial side of this mining area be adequately written, it would form a voluminous record of facts and figures connected with the dealings of speculators of slight scientific interest. Some of the rich repositories of tin and copper ore have yielded immense fortunes to their lessees and to the lords of the soil. This is now changed, and there remains a wilderness of mine burrows, engine houses, and smoke stacks, spoiling the appearance of the country, but bearing mute witness to the prosperous mining days of the past. Since 1865 the decline was fluctuating but gradual, as first copper and then tin suffered from outside competition. It should, however, be remembered that with mining at greater and greater depths the expenses of working (pumping, hauling, &c.) increased to an extent sufficiently great to seriously affect the industry, and with many of the richest ore bodies already worked out, the condition of the mines contributed in no small degree to the final collapse. The disastrous drop in the price of tin about the middle of the seventies saw the closing down of many mines which had the price been maintained might yet be working. The value of tin ore at the present time is so high that as time goes on it may be confidently expected to once more raise the status of Cornish mining. The only barrier to immediate progress in this direction appears to be the difficulties which will have to be encountered in opening up the old sites already so extensively explored, since the ramifications of levels and working places are such as to present a difficult problem in the unwatering of the submerged mines, many of which are connected underground by a vast system of drivages. There is brightness, however, in the reflection that a few of the mines have survived the period of depression, and one at least has worked without cessation for over 150 years, and still holds a high place in the tin-mining world, being the largest, deepest, and most productive tin mine in existence.

In the preceding pages it has been found necessary to make constant use of published works on the district, since so few of the mines are now accessible. Among the more important publications those of De la Beche and Henwood have been of great service. In later times the names of Collins and Le Neve Foster are intimately connected with Cornish mining. The ancient History of Cornwall has been written again and again, but the leading works are those of Carew, Camden, Borlase, Hawkins, De la Beche, and Hunt. In this memoir an attempt has been made to deal with the various points of interest to miners in the region. In the methodical treatment which is adopted there is no claim to originality, but some of the old problems have been revived and viewed in a new aspect. The alluvial, or stream tin-deposits, which have been so well described by Henwood, and others, are now exhausted, but their origin and mode of occurrence have been discussed by Mr. Hill in Part I. of this memoir.

The tables, which give the detailed output for individual mines from 1815 onwards, should be regarded as a general measure of the relative importance of the mines, and not as being strictly accurate, since in former days the records were not preserved so carefully as they have been latterly.

In conclusion, it should be mentioned that assistance has been freely given by Mine Captains and others, who have afforded every facility for observations underground.

In Cornwall the survey is indebted for much information to the Duchy Office, the Estate Offices of Tehidy and Pendarves, and to Messrs. Henderson & Son, of Truro, and others, where mine plans and records have been placed at our disposal. In London similar facilities have been afforded at the Home Office and the Office of Woods and Forests. The scales to which the mine plans are drawn vary from 4, 6, 8, 10, 12 to 20 fathoms to the inch, of which 8 fathoms to the inch is the commonest.

History of the Mining Industry.

There are good reasons for the belief that the Phœnicians exported tin from Cornwall several centuries before the Christian era. Borlase states that the Romans and Greeks also "studiously insinuated themselves into the same traffic." Until the middle of the 13th century Cornwall was the most important source of tin, but the ore was obtained from alluvial deposits and the backs of the lodes, the latter of which were worked away, leaving open cuts called "coffins" or "goffins." The works of Pryce and Borlase give excellent accounts of the early history of mining, and are of particular interest as dealing with the time about which the steam engine was introduced, and it may be said that it is from this period that the working of tin and copper ores became an important national industry. The main obstacle in early times to the progress of deep mining in Cornwall was the inability of the miners to cope with the subterranean water which flooded the excavations. Before the intro-

duction of the steam engine the water was raised in kibbles by means of a whim worked by horses. The Rag and Chain pump* was another device for lifting water. The old "Fire Engine" is the first steam pump, and, as modified by Trevithick, was a great advance on earlier appliances. The most important invention was made by Newcomen, whose Cornish pumping engine, with Watt's modification, was destined to assist mining operations enormously. Prior to this the mines could not be worked to great depth, and the old Pool Mine, for instance, was only 55 fathoms in depth at the time Borlase wrote, while the deep workings of Bullen Garden Mine were in 1778 only about 90 fathoms from surface. As Borlase quaintly remarks, it was necessary "that to obviate the inconvenience (of water) the captain should be a kind of engineer."

The introduction of gunpowder in the Cornish mines about the beginning of the 18th century was another important advance in mining work.

Pryce gives an interesting account of the state of copper mining at the period of its inception, and says that the people were ignorant alike of its value and the modes of dressing it. Thus, he states in 1778 that "though the richness of our copper works is not a late discovery, yet it is not a hundred years that the knowledge of working them to good effect hath been understood." About the year 1700, some Bristol merchants, by their interest in the copper mines, stimulated the industry, while about 1730 large quantities of copper ore were raised from Roskear, Pool, and other mines, in spite of the prevailing local ignorance of the value of the ores.

From 1726 onwards the yearly output is tabulated in the statistical table, and a perusal of those tables will show that the output increased fairly steadily year by year until past the middle of the 19th century, when the decline commenced. The richest and most accessible ores were rapidly being exhausted, and the prices for copper ore had fallen off owing to outside competition. With increasing depth, many of the mines yielded tin ore in such quantity as to warrant their exploitation for tin instead of copper, so that many mines once yielding copper ore exclusively now yielded tin ore in abundance, and transferred the attention of investors to tin mining. (Fig. 64.)

From 1750 to 1800 the tin mines were yielding a tolerably uniform annual amount of black tin, but early in the last century they commenced to increase their output, and there was a steady rise in the annual returns of black tin up to the sixties. From the seventies to the present time, although the output has been fairly well maintained, it gradually decreased, while in the last ten years it has fallen off considerably. Foreign competition so lowered the price of tin ore that many mines failed in the seventies. For several years past the price of black tin has been increasing, and there is every reason, should the record high figure now

* Invented by Captain Savory, of Exeter. Borlase, *Nat. Hist.*, *Corn.*, 1758, p. 170.

reached be maintained, for looking forward to the opening up of many of the old mines.

The statistics published by the Home Office since 1881, and those contained in the Memoirs of the Geological Survey, show that the number of working mines has suffered a great decrease in the last fifty years. The following tabular statement gives the number of mines in this district which at the various dates were yielding tin or copper ores. Many of the mines were, of course, yielding both ores:—

	Mines yielding Tin ore	*Mines yielding* Copper.
1858	50	70
1863	56	90
1868	48	52
1873	74	40
1878	36	30
1883	42	20
1888	32	10
1893	25	6
1898	16	3
1903	15	5

The amount of copper ore produced from the mines in the Camborne area in late years is only a few tons per annum, and is scarcely worth consideration, some of the ore being obtained while prospecting old sites.

The following tabular statement of the outputs of three prominent mines which are still working is of peculiar interest, as it traces the evolution of mining from the upper levels to the deeper-seated zones, accompanied by the substitution of tin for copper:—

	Dolcoath.			Wheal Basset.			East Pool.		
Year.	Copper Ore.	Metallic Copper.	Black Tin.	Copper Ore.	Metallic Copper.	Black Tin.	Copper Ore.	Metallic Copper.	Black Tin.
	T. Cwts.	T. Cwts.	T. Cwts.	T. Cwts.	T. Cwts.	T. Cwts.	T. Cwts.	T. Cwts.	T. Cwts.
1845	3,504 0	233 14	...	...	...	...	929 0	73 5	...
1846	2,156 0	138 12	...	...	...	...	633 0	43 15	...
1847	2,057 0	135 8	...	...	...	...	608 0	34 2	...
1848	1,254 0	95 2	...	...	...	...	1,088 0	64 16	...
1849	1,028 0	77 10	...	...	...	...	1,136 0	66 17	...
1850	1,115 0	72 11	...	...	...	...	1,422 0	70 2	...
1851	801 0	55 8	...	5,442 0	487 17	...	2,050 0	106 16	...
1852	832 0	42 14	...	5,966 0	503 13	21 0	1,740 0	86 10	20 16
1853	1,040 0	51 17	360 0	7,207 0	608 2	31 0	2,157 0	98 11	22 0
1854	992 0	45 10	363 10	8,378 0	646 9	46 0	2,034 0	99 4	49 11
1855	711 0	28 6	352 7	7,713 0	680 12	25 11	2,287 0	134 13	38 8
1856	617 0	24 8	416 13	7,600 0	594 18	20 0	2,821 0	178 14	49 13
1857	566 0	25 18	544 0	6,183 0	...	32 3	2,535 0	138 19	51 9
1858	593 0	34 8	635 10	4,754 0	414 4	45 4	1,300 0	66 15	36 7
1859	757 0	38 15	723 18	4,258 0	365 13	42 9	1,280 0	54 15	44 2
1860	712 0	28 14	805 1	3,894 0	300 14	60 1	1,896 0	93 9	58 5
1861	417 0	18 18	864 7	2,931 0	231 19	51 15	2,435 0	120 6	49 15
1862	508 0	29 16	985 19	2,599 0	211 17	48 18	2,944 0	149 8	97 8
1863	636 0	39 16	1,026 9	1,998 0	154 0	77 16	3,264 0	155 16	134 17
1864	621 0	39 3	1,029 18	1,726 0	138 5	117 7	2,805 0	126 3	136 18
1865	607 0	44 13	944 9	2,036 0	183 11	158 10	2,083 0	93 9	257 1

Year.	Dolcoath. Copper Ore.	Dolcoath. Metallic Copper.	Dolcoath. Black Tin.	Wheal Basset. Copper Ore.	Wheal Basset. Metallic Copper.	Wheal Basset. Black Tin.	East Pool. Copper Ore.	East Pool. Metallic Copper.	East Pool. Black Tin.
	T. Cwts.	T. Cwts.	T. Cwts.	T. Cwts.	T. Cwts.	T. Cwts.	T. Cwts.	T. Cwts.	T. Cwts.
1866	688 0	52 1	919 7	2,108 0	174 9	167 3	1,808 0	97 9	379 13
1867	267 0	15 18	847 18	1,700 0	132 7	292 13	1,582 0	76 14	321 8
1868	153 0	12 11	984 4	1,539 0	115 12	264 17	1,753 0	79 15	364 14
1869	153 0	10 11	813 8	1,572 0	130 8	313 4	1,641 0	85 0	325 8
1870	57 0	3 17	1,034 15	1,341 0	106 12	353 9	1,854 0	90 14	351 17
1871	86 0	5 11	1,169 18	442 0	35 2	335 2	2,430 0	125 12	109 19
1872	46 0	3 3	1,284 16	528 0	38 8	255 7	2,520 0	138 8	90 14
1873	16 0	1 1	1,045 6	488 0	67 1	286 6	1,933 0	95 17	384 1
1874	75 0	5 16	1,120 19	396 0	41 8	310 18	1,920 0	95 9	419 18
1875	...	...	1,241 10	714 0	62 17	248 0	1,823 0	85 12	571 5
1876	41 0	2 8	1,263 5	759 0	67 13	147 6	1,806 0	90 18	364 1
1877	30 6	2 1	1,404 13	448 9	40 10	164 8	1,527 0	90 12	392 0
1878	13 11	0 12	1,539 2	227 18	23 8	208 6	2,564 11	151 4	489 15
1879	4 4	0 3	1,780 8	99 2	8 0	23 0	2,362 7	112 10	864 9
1880	...	...	1,737 14	29 12	2 0	7 15	1,350 3	75 13	1,268 4
1881	...	...	1,816 5	...	...	8 4	903 18	45 15	1,317 14
1882	...	...	1,976 3	...	...	60 9	380 16	19 1	1,536 2
1883	...	...	1,875 12	...	...	173 10	48 0	2 10	1,402 0
1884	...	...	2,423 3	...	...	267 3	376 0	...	1,573 0
1885	...	...	2,555 3	...	...	395 0	229 0	...	1,512 0
1886	...	...	2,383 0	...	...	379 4	...	...	1,440 0
1887	...	...	2,366 0	...	...	370 0	...	...	1,233 0
1888	...	...	2,239 0	...	...	416 9	15 0	...	1,179 0
1889	3 0	...	2,125 0	...	...	386 10	26 0	...	1,105 0
1890	...	...	2,023 10	3 0	...	396 0	312 0	...	995 0
1891	...	...	2,131 12	...	...	402 0	451 0	...	1,070 17
1892	...	...	2,535 0	...	...	458 0	15 0	...	1,004 0
1893	...	...	2,421 9	...	...	432 10	729 0	...	938 7
1894	...	...	2,126 0	...	...	470 4	730 0	...	940 0
1895	...	...	1,766 0	...	...	536 4	373 0	...	877 0
1896	...	...	2,039 7	...	...	554 0	...	...	529 6
1897	...	...	2,095 0	...	...	539 0	64 0	...	309 0
1898	...	...	2,302 7	...	...	356 0	16 0	...	770 0
1899	4 0	...	2,078 18	...	...	268 0	22 0	...	816 0
1900	...	...	2,004 8	...	...	523 0	...	...	739 0
1901	...	...	2,035 11	...	...	575 0	10 0	...	699 0
1902	...	...	1,828 9	...	...	794 0	31 0	...	663 0
1903	...	...	1,739 17	11 0	...	728 0	27 0	...	706 0
1904	...	...	1,705 4	...	...	613 0	863 0	...	661 0
1905	...	...	1,696 16	...	...	768 0	70 0	...	585 10

Notes on Tin-Ore Dressing in the Camborne Area.

Older Methods.—Writing over a century and a half before Borlase, Carew,* in his quaintly-worded description of Cornwall, gives a very good insight into the state of mining at that time.

Among other subjects the dressing of ore is dealt with, and from Carew's account the methods in use in his time were very simple. The ore was first broken with hammers "and then carried to a stamping mill, where three, and in some places six, great logs of timber bound at the ends with

* *Survey of Cornwall*, 1602.

iron, and lifted up and down by a wheel driven with water, do break it smaller. If the stones be over moist they are dried by the fire in an iron cradle or grate. From the stamping mill it passeth to the crazing mill, which between two grinding stones, turned also by a water wheel, bruiseth the same to a fine sand; howbeit of late times they mostly use wet stampers and so have no need of crazing mills for their best stuff but only for the crust of their tails."* After the stuff was stamped it was spread on a sloping green turf and "softly tossed" while a current of water flowed through it and washed away the waste.

The processes of tin ore dressing about the middle of the 18th century have been well described by Borlase,† and later by Pryce,‡ who utilised the same diagram as Borlase to illustrate his description. Borlase remarks that the ore was passed under stamps weighing 140 lbs. apiece. The grating was a plate of metal 1 foot square and $\frac{1}{10}$ in. in thickness, and was "full of small holes punched in it about the bigness of a moderate pin." The pulp from the stamps passed through three pits in succession, making a settlement in each according to density. The material from the first or fore-pit was the richest. The stuff from the other two pits was known as the "slimes." The overflow from the pits went to waste. The contents of the fore-pit were dug out and treated in a buddle 7 feet long, 3 feet wide, and 2 feet deep. The tin-dresser stood in this pit and spread the material on a plane sloping surface at the head of the buddle; the stuff being spread in the form of a series of small ridges parallel with the direction of a current of water which passed over the plane from a launder, or trough. In this way the slime was washed out of the stuff, and the whole of the material fell over into the pit in which the tin-dresser stood, and there settled in three grades, according to quality; that nearest the head being the purest. The head was put into a kieve (or tub) and washed by stirring (tozing or tossing) for a quarter of an hour, so that the light waste rose to the top, which after settling was skimmed off. The rich part at the bottom of the kieve had to be rebuddled, and again put in kieves. Finally, it was "packed" by smartly tapping the kieve with a hammer, so as to shake the heaviest minerals to the bottom. The skimmings were saved and treated with other products. The two other classes of stuff from the first buddling operation underwent a similar treatment. The slimes which were deposited in the second and third pits just below the stamps were treated in a different way from that in which the coarse material from the first or fore-pit was treated. The slimes were conducted to a pednan (or circular pit) where they were stirred, and made gradually to overflow into a long pit divided into two parts. The part near the pednan was smaller than that further away, which was 10 feet long, 3 feet wide, and 8 inches deep, and separated from the smaller by a wooden partition. The material from the pednan passed successively over into the two parts of the long pit. In the larger part of the pit the stuff settled in two grades. That at the head of the pit was dug out and passed over frames, while that at the tail was carried back to the small part of the pit just below the pednan, where it was again washed (or "trunked") over before it could be treated in frames. The frame consisted of two plane surfaces of timber called respectively the head and the body. The ore was spread over the head in the form of a series of ridges parallel with the direction in which a stream of fresh water was flowing from a launder over a distributing arrangement similar to that employed in the buddling operation. The stuff was carried gently forward by the current on to the body of the frame, which was slightly inclined, and then the heaviest material, however fine, settled, while the lightest flowed to waste. When a thin layer of concentrate was deposited, the plane was tilted up by one of the lateral edges and the material washed off by a spray into a wooden chest. When the chest was full the stuff was treated in kieves and tozed, sifted and packed. The sieving took place under water in the kieve, and

* *Op. cit.* edition published with notes by Tonkin in 1811, p. 39. See also Heath, "Account of Scilly," 1750.

† *Nat. Hist. Corn.*, 1758, p. 178.

‡ *Min. Cornub.*, 1778.

by agitating a sieve in which some of the stuff to be dressed was placed, the material was cleansed of very fine particles of waste, and the coarse waste remained in the sieve. The concentrate from the kieves might be taken to the frames and again washed, only once more to be tozed in kieves. Borlase states that a hundred sacks, each containing 12 gallons of dressed tin ore, could, in the space of a few days, be dressed for 50 shillings by this process.

Pryce has described the process known as dilleughing, which is simply a method of cleansing the concentrate from the kieves by means of a fine hair sieve* which was pressed down on the water and turned round with a swaying motion so as to arrange the materials it contained according to their specific gravity, the operation being assisted by the sorting action of the water coming in through the bottom of the sieve. When this was accomplished the poorer material covering the waste was skimmed off into a kieve to be treated again.

In 1828 Henwood gave an account of the dressing of tin ore in Cornwall,† but beyond the fact that the stamps were heavier, and that there was a general improvement in details, as was only natural with the increasing importance of tin mining, the general principles of treatment seem to have been much the same as in the time of Borlase. At the present time there are several of these old-style dressing plants to be seen—particularly in the St. Austell district. A still later work, which includes notes on the treatment of ores in Cornwall, is Hunt's "British Mining" (1884), while Le Neve Foster's recent book, "Ore and Stone Mining" (1900), refers frequently to Cornwall in the sections on ore dressing.‡

Dressing Machinery at Present in Use.—In the last few years considerable improvements have been effected in processes for the preparation of black tin for the market, and although at the present time no two mines employ exactly the same process there is a general similarity in the arrangement of the plants of the larger mines.

The following descriptions refer to the more important appliances actually in use in the mines of the Camborne district. A short description of their action may also be of interest, although most of them have received attention in other works:—

Three well-known types of stamps are used in the mines of the Camborne district—(1) The old Cornish stamp (Plate XIII.), (2) the Californian stamps, and (3) Husband's pneumatic stamps. The old Cornish stamp is still used for crushing in many mines, but in recent installations the more efficient Californian stamp is employed. The Cornish stamp requires but little attention and was the type employed throughout the most prosperous mining days of the last century. Each head weighs about 700 lbs., but is frequently less. The Californiam stamps, which possess the advantage of improved cams and rotating shanks, weigh from 800 to 1,200 lbs. apiece, and are designed to deal about 80 blows a minute. Those used at Dolcoath have been described by Josiah Thomas, who remarks that each iron coffer or mortar box takes five stamps, and that each set of ten stamps is worked from a separate belting. The cam shafting is 5 inches in diameter. Each head weighs 800 lbs. and with a 9-inch drop deals 80 blows a minute.§ The head deals two blows during one revolution of the cam shaft, so that with a 5-stamp battery 10 blows are delivered for each revolution of the shaft. Each head of Californian stamps crushes from $1\frac{1}{2}$ to 3 tons of the hard blue veinstone daily, and on easier stuff can crush much more than this.

The screens usually employed are perforated plates, as they are more

* *Min. Cornub.*, 1778, p. 223; or De la Beche, Geological Report, p. 578.

† On the manipulations to which the ores of tin and copper are subjected in the Central Mining District. *Tr. R.G.S. Corn.*, vol. iv., p. 145.

‡ A useful modern book of reference on ore dressing is one by R. H. Richards (U.S A.), 1903.

§ The new Californian stamps at Dolcoath Mine. *Journ. R. Inst. Corn.*, vol. xii., 1193, p. 39.

durable than wire gratings, although the use of the latter, by affording a better chance for the passage of the pulp through holes of a given size than in the case of perforated plates, prevents the production of an undue quantity of slime, which would otherwise be formed if the pulp were kept too long in the mortar box, by being unable to pass freely through the screen. This is one of the points which should be borne in mind in view of the enormous amount of tin which is annually lost to the mines of this district in the form of slime. Common sizes for perforated plates are Nos. 36 or 37, and for wire gratings 20 or 25-mesh (400 to 625 holes to the square inch). In the veinstone in the deep parts of such mines as Dolcoath, Wheal Basset, &c., a fine degree of stamping is necessary owing to the fineness of the particles of black tin, so that the production ol a certain amount of slime is unavoidable.

An important innovation in ore-dressing appliances has been made during the last twenty years in the introduction of the Frue vanner (Plate XIV.). These machines are now used in most of the mines for the first treatment of the pulp as it comes from the stamps. The principal part of the machine is a broad endless belt which travels continuously in a nearly horizontal direction supported on rollers. The upper surface of the belt, which is slightly inclined, travels upwards towards the end at which the pulp is fed on. An excentric at the side of the machine communicates a lateral oscillating movement to the belt. The action is as follows:—The pulp passes on to the belt from a distributing arrangement situated at the end towards which the upper part of the belt is travelling. The heavy mineral grains sink on to the belt, and, owing to their weight, are enabled to pass under a series of jets of water, and to be carried over the end of the machine with the belt, where they are washed off in a trough of water situated below the belt. The lighter particles of veinstone are, on the contrary, carried back with a current of water down the incline in a direction opposite to that in which the belt is travelling. The concentrate from the Frue vanner contains, in addition to black tin, a little coarse quartz, tourmaline, sulphides, &c. The tailings consist of grains of quartz, tourmaline, and other minerals, in addition to fine slime, which usually contains black tin in a fine state of division. The oscillating movement prevents the material from clogging. The inventors state that no initial classification of the pulp according to size is required, and that too much water interferes with the efficient action of the machine. By using only sufficient water to render the pulp free-working, it is claimed that a considerable amount of slime tin is retained in the concentrate, owing to the interference of the layer of material on the table with the flow of water, which otherwise would carry away the slime tin. This explanation however, if true, leads to the supposition that coarser veinstone waste is also retained by the same cause, which implies an imperfect separation, which is not the case, since the machines with a fair quantity of clear water act efficiently. The amount of pulp which can be treated on a Frue vanner daily is from 5 to 10 tons.

Wilfley (Plate XV.) or Buss tables are bumping tables employed for separating sands containing black tin. In some mines they are used to make the initial separation of the pulp in place of Frue vanners, but at Dolcoath Mine a Wilfley table is used at a later stage in the process of the preparation of black tin. Broadly speaking, the table is a rectangular frame slightly inclined in a direction at right angles to its length. At one end an oscillating or bumping movement is imparted to the table by an excentric. A number of wooden strips, or riffles, of varying length, and an inch or so apart, are fixed to the table from the short edge at the feet end, parallel with the longer edges of the table. The longest strips are near the lower edge of the table, and the shorter near the feed or upper edge. The object of these strips is to interfere with the pulp as it flows down the table, in such a way that the current is prevented from having a dominating influence over the effect of the shock produced by the excentric. The heavy particles of the pulp which is fed on at one end of the long upper edge of the table commence to traverse the table in a diagonal direction near the ends of the riffles, being carried forwards by the influence of the

shock imparted to them by the table, and downwards by the flow of a current of clean water issuing from sprays in a pipe extending along the upper edge of the table. In this way black tin, some tourmaline, large grains of quartz, &c., travel diagonally down the table but gradually separate into two or more streams, according to the density of the minerals. These products are caught in separate launders. The lightest mineral waste or flakey minerals are generally carried over the riffles by the water and are conducted away in a special launder.

In using these tables it is obvious that the best results are obtained when the material consists of grains of uniform size; that is, the material should be classified before treatment.

In the later stages of tin dressing revolving frames are used, and there are many modifications of them. They all consist of a circular revolving deck of the shape of a shallow convex or concave cone. Some of them are double decked. They are generally employed in the concentration of slime tin. In the concave tables, such as those made by Bartle, the slime is fed on to the table from a fixed distributing arrangement. The stream at once commences to flow inwards—the heavier particles lagging behind the lighter. As the table revolves the deposit is brought under the influence of a gentle stream of clean water which washes away the waste. When the table has nearly completed a revolution all that is left on it at this particular segment of the table is a rich concentrate, which is readily washed off by a powerful spray into a separate launder. The arrangement is automatic and continuous.

The double-deck revolving tables are merely modifications of the above. Instead of one large deck there are two decks placed concentrically, revolving on the same axis. At certain points the concentrate from the outer deck is washed off, but the tailings flow on to the second deck and undergo a further separation. The Acme table (Plate XVI.) is a new modification of the double-deck table. The tables are concentric, but the outer one is concave while the inner is convex. The tails from the outer deck are led into a launder and lifted by a raft wheel and delivered on to the inner deck where the material is again separated.

Buddles are circular pits employed in the last stages of tin-ore dressing. The floor of the buddle slopes downwards from the circumference to the centre (concave buddle) (Plate XVIII.), or from the centre to the circumference (convex buddle) (Plate XVII.) In the case of convex buddles the ore is distributed at the "head" or centre of the buddle over a cone-like distributor. In concave buddles, the ore is distributed at the circumference by means of radial trough-shaped arms, which revolve round a vertical axis at the centre of the bed. In either case light brushes suspended from radial arms sweep over the surface of the deposit to keep it even. Where the stuff under treatment has to be "buddled" several times the convex buddle is used first, as a rule, the final operations being carried out in the concave buddle. In the convex buddle the velocity and volume of the stream of ore flowing over any unit area is greater at the head of the buddle than at the circumference or "tail," so that the action is more vigorous than that which takes place in concave buddles, where the reverse is the case. The minerals are not washed off as in the case of revolving tables, but are allowed to accumulate until the deposit is about a foot or less in thickness. The machine is then stopped and the various qualities of stuff, arranged in concentric annular deposits, are dug out and each treated separately.

A Dumb pit (Plate XIX.) is a small convex buddle in which a rough classification is effected at a certain stage in dressing. It is a very simple arrangement. The material is poured into the middle of the bed in a thick stream from a pipe. The heavier minerals remain in the middle of the pit while the lighter are washed to the circumference where they settle. When the pit is full the stuff is dug out in annular sections, and, according to its quality, treated in different ways.

The last operation in the preparation of black tin for the market takes place in kieves (Plate XX.), or large tubs. The dressed tin ore already

highly concentrated is stirred up in the kieve with plenty of water ("tozed"). It is then allowed to settle while the tub is smartly struck on the outside with a hammer or crowbar ("packed"). The effect of this is to make the lighter stuff rise to the top, where it can be skimmed off. The rich concentrate below is then ready for market.

Plane tables or ragging frames are used for the treatment of tin-bearing slimes which have already been treated in the dressing yards, and would otherwise be thrown to waste. It is this appliance which is so extensively used on the tin stream works for treating the material which is regarded at the mines as waste. Each consists of a fixed rectangular frame over which the slime is distributed from a trough or launder which feeds a series of these frames. The heavier particles from the slime remain on the table while the lighter stuffs flow to waste. After a minute or so a fair amount of concentrate has settled on the table, and this is washed off by a cascade of water which is dashed over the surface from a trough, which topples over automatically when it is full of water. At the same time an arrangement at the foot of the table, actuated by a lever connected to the toppling trough, directs the concentrate into a special launder.

The most recent innovation is the Wetherell electro-magnetic separator, which is being used for the extraction of wolfram from the ore at East Pool Mine. The separation of cassiterite and wolfram is almost impossible by ordinary dressing methods, owing to the similarity in density of the minerals. A series of costly experiments was carried out at East Pool Mine in attempting to solve this problem, and at one time it was hoped that the fusion of wolfram with soda, so as to produce sodium tungstate which is soluble, would be a feasible method. Tungstate of soda was produced at East Pool Mine for a few years in this way, but eventually the process was dropped as being too unprofitable. The separator seems to be doing good work, and as wolfram is now at a high price the use of these machines may become more common.

The partially dressed ore containing tin and wolfram, after having been calcined, contains a certain amount of "iron" which is also extracted by the magnetic separator.

The "iron" impurities are derived from two sources: (1) iron oxides resulting from the decomposition of iron pyrites during roasting, and those originally present in the ore, and (2) metallic iron, from the wear and tear of the stamps and other machinery used in handling the ore. The following is an account of the action of the separator:—

The ore from the calciner, after being allowed to cool, is distributed on to a travelling belt. Above the belt are arranged four electro-magnets, under which the ore passes successively as it travels along with the belt. Under the poles of each magnet there is a narrow india-rubber band, which travels at right angles to the belt, upon which the ore is spread. By this means magnetic particles passing under the bands are picked up in a continuous stream, and carried laterally on the lower surface of the bands towards and over the edge of the belt, where passing out of the magnetic field they fall into a box. The first two magnets pick up iron and iron oxides. The next two are more strongly magnetised and pick up wolfram. The black tin with veinstone particles travels along with the belt and falls over into a box. The wolfram, from the last magnet at least, may have to be passed through the machine for a second time to free it from a little oxide of iron and also cassiterite dust, which is carried along in the current of wolfram particles as they leap up to the magnets. Before it is ready for the market the wolfram requires treatment on a hand buddle.

The machine is designed to treat about 10 tons of concentrates daily. If the ore which is being treated contains copper this is picked up with the oxide of iron resulting from the decomposition of copper pyrites and so does not pass over the belt with the tin.

Present Methods of Ore Concentration.—The ordinary processes in the preparation of black tin for the market in the Camborne area have a general uniformity. In other parts of Cornwall recent installations of dressing plant are quite different from that used in Camborne. In the

eastern part of Cornwall the aim has been to reduce manual labour by arranging the appliances so that the products from the different machines can be led from one place to another automatically. In addition to this the general principle is one in which the materials are classified according to the speed with which they fall through water, by means of spitzluten and spitzkasten.

The following is a brief general account of the actual processes in use in the Camborne Mines:—

The ore which is broken in the stopes is roughly selected underground by the miners, and that which is worth treating is hauled up to the surface and there dumped on to the spalling floors, where women and elderly men are employed under cover to still further separate, by means of sledge hammers, the ore-bearing parts of the rock from that which is waste. The ore is then carried to the stamps, or, if any of the lumps are too large, they are passed through Blake Marsden or other rock-breakers and then led to the stamps.

The pulp from the stamps is splashed through perforated plates (gauge No. 36), and then passed on to Frue vanners. Perforated plates are used in preference to the wire gratings, owing to their greater durability. On the vanners the pulp is separated into concentrates and tailings. The concentrates are taken to a calciner and roasted, and then mixed with water and roughly classified in Dumb pits. Two products are obtained in this way—"Head" near the centre of the pit, and "Tailings" near the circumference. The head is treated in buddles or on Wilfley tables, after which it proceeds to the kieves. If sufficiently rich, the use of the Wilfley tables and buddles is dispensed with, and the material is transferred to the kieves direct. In the kieves it receives final treatment, the marketable product being known as "crop tin." If a Wilfley table has been used the tailings from it are sent back to the stamps. The "tailings" from the Dumb pit are pulverised in a rotary pulveriser, and treated on revolving tables and buddles, and finally in kieves. The black tin from this operation is known as "fine tin."

The tailings from the Frue vanners are led into an upward current separator, which is a box in which there is an upward flow of water regulated by a tap. Two products are obtained. The finer material, known as slimes, is buoyed up by the current and overflows into a launder, while the coarse material, called sands, passes out through another opening into launders known as "strips." The heavier portions of the sands collect in the strips and are dug out periodically, when they are again pulverised and treated on vanners. The light part of the sands passes out of the strips and flows to waste. When the vanners are treating the heavy part from the strips the tailings from them are treated on ragging frames.

The slimes from the separator flow over into settling pits, after which they are treated on ragging frames. The concentrates from the frames pass into settling pits and then over revolving tables, after which the "head" is calcined. After calcining the slime is again treated on revolving tables, and the concentrate known as "slime tin" is ready for sale. The tailings from the ragging frames go to waste.

At King Edward Mine (situated on part of the South Condurrow sett), a tin-dressing plant has been erected for the instruction of students of the Camborne Mining School. The general arrangement is as follows:— The pulp from the Californian stamps flows successively through three compartments of a set of spitzluten. The coarse material from the first compartment is treated on a Buss table; the material from the second is treated on a Frue vanner, and the finer stuff from the third compartment is led to a settling pit, from which it passes on to an Acme table. The tailings from the Buss table are pulverised and again passed through the spitzluten. The head from the Acme table is then roasted. The concentrates from the Frue vanner and Buss table are also roasted before being treated further, but these products are kept separate. The overflow from the last compartment of the spitzluten goes to pyramidal settlers, and the various grades of material so produced are treated on ragging frames. The head is roasted, and is known as "slime" tin.

The methods of dressing the tin ore have so far improved in recent years that ore containing as little as 1 per cent. of cassiterite can be mined with profit, provided the veinstone is not too hard and has not to be hauled a great distance. It should also be remembered that the working expenses in treating a certain quantity of stuff at a mine is not necessarily doubled by doubling the amount under treatment. Advantage is taken of this fact in several mines where a large quantity of fairly good stuff is treated with as little handling as possible, where formerly less but richer stuff was considered the proper course.

At Dolcoath the output of the mine in the last ten years has been nearly doubled, reducing the average produce of the mine from 79 down to 36 lbs. of black tin per ton of ore. The dressed product, known as black tin, when ready for the market, generally contains under 65 per cent. of metallic tin. The Home Office Report for 1904 states that for that year the average amount of metallic tin obtainable from ordinary black tin was a little over 63 per cent., while the amount obtainable from stream works ("slime tin") was a little over 46 per cent.

There can be no doubt that many of the old burrows contain sufficient tin ore to pay for the cost of treating them. In fact, many of the old heaps, and particularly the waste sands or tailings from former dressing operations, could, where there is a large quantity of them, be profitably worked at the present time. Where the mine was originally only worked for copper or arsenic, the burrows may be exceptionally rich in tin ore. It is stated for instance, that the huge pile of tailings situated on Carn Brea Mine sett contains 8 lbs. of black tin to the ton, and is valued at £200,000, of which a great deal would have to be spent in obtaining the tin. Pryce,* who resided at Redruth, makes the following statement with regard to the copper contained in some old heaps:—"Even burnt leavings of tin are often considerably valuable, especially if they are cupreous; and even the poorest of these leavings bring 10s. or 20s. a ton; which is better than to throw them away as was the case no further back than 40 years. All burnt leavings taken from tin stuff till 1735 were esteemed good for nothing. But in that year there were several parcels lying on sundry stamp plots in this parish which induced Mr. Morgan Bevan, an old experienced assayer, to try whether he could reduce them to metal. For the first time he essayed a sample of three tons, and to his own great surprise as well as that of others, he found he could give £7 4s. 6d. a ton for them, which he actually did, and presently after bought several parcels more of Messrs. Carter, Reynolds, Penrose, Cornish, &c., the principal tin dressers of those days. From that time all burnt leavings were taken care of, provided they were sufficiently impregnated with copper." Pryce instances Chacewater Mine burrow as a case in point.

At the present time an enormous quantity of black tin is annually lost to such mines as Wheal Grenville, Dolcoath, Carn Brea, East Pool, South Crofty, and Wheal Basset, in the form of slime tin, the complete saving of which is a problem as yet unsolved. In the event of such solution the many stream works situated below the mines on the Red River and the river which runs down from Wheal Basset would become idle. In 1904 over £37,000 was realised by the sale of black tin extracted from the refuse of these mines by stream work companies situated on the rivers below them.

In the dressing of tin ore it is important to ascertain the true nature of the stuff which is being treated. If a highly concentrated black tin is obtained at the expense of a loss in the form of slime tin in its production it may prove unremunerative solely from the escape of valuable mineral products into the river.

Examination of the Products from the Various Operations in the Dressing of the Tin Ore.—Samples of the various products obtained in the different processes of tin ore dressing have been mounted for microscopic examination, and the slides photographed. The sands shown in the plates are photographed in ordinary transmitted light and magnified 20 times. (Plates XXII., XXIII.)

* *Min. Cornub.*, 1778, p. 230.

The amount of cassiterite present in the sands has been estimated by the method of reduction in hydrogen, in the laboratory at Jermyn Street, with the assistance of Dr. Pollard.

The series of tin washings described below was obtained from the South Crofty dressing floors on the 21st June, 1904. The descriptions of the products refer to the dried sample, the moisture present varying from ·08 per cent. to ·4 per cent.

The ore from the mine contains cassiterite, copper pyrites, mispickel, and associated veinstone minerals, and possibly some wolfram.

The pulp from the stamps is shown in Fig. 1, Plate XXII. It is a speckled grey sand containing 1½ per cent. of cassiterite. Under the microscope the grains are seen to vary in size from fine dust to fine sand with large grains. On sizing the material by means of sieves less than 2 per cent. remains on 30-mesh, 22 per cent. remains on 60-mesh, 20 per cent. on 90-mesh, 10 per cent. on 120, and 46 per cent. passes through 120-mesh sieve. The minerals present are felspar, quartz (with fluid cavities), tourmaline (brown and blue), fluorspar, chlorite, a little mica, and zircon. Cassiterite occurs generally in small grains, and there is also present copper pyrites, mispickel, hæmatite, ilmenite, and some hydrated oxide of iron, and a little chalybite. Some of the larger fragments seen in the plate consist of felspar and quartz with dusty inclusions. The clear grains are quartz, fluorspar, felspar, &c. The minerals in half-tone are tourmaline, chlorite, &c. Cassiterite is also represented in half-tone, and is often seen strongly bordered. Some of the minerals are opaque, owing to dusty inclusions in felspar, quartz, &c., but there is also present copper pyrites, mispickel, and minerals with dark tints, deep green, blue and red.

The pulp from the stamps passes to the Frue vanners, and Fig. 2, Plate XXII., shows the concentrate obtained from them. It is a fine, slightly gritty sand, with a brownish hue, and contains 21 per cent. of oxide of tin. Under the microscope the grains are seen to be small, but some are as large as $\frac{1}{16}$ of an inch across. In sizing by sieves 3 per cent. remains on 30-mesh, 11 per cent. on 60-mesh, 11 per cent. on 90-mesh, 4 per cent. on 120-mesh, and 71 per cent. passes through a sieve of 120-mesh. The grains consist of cassiterite, pyrites, ilmenite, zircon, &c., with a considerable amount of fluorspar, tourmaline, quartz, and chlorite. The larger grains are quartz (with included tourmaline needles), cassiterite, pyrites, chlorite, and iron oxide. There is a little felspar. The cassiterite grains are generally subangular.

The concentrate from the Frue vanner is then calcined. After calcining the material is of a dark, slightly brownish red colour. The only difference between this material and the one just described is that the sulphides are destroyed while there is an increase in the amount of oxide of iron. There has also been a tendency for some of the grains to clot together, but they are broken up in the pulveriser. This material is treated in a buddle. The "head" from the buddle is not shown in the plate, but it is a very fine dark purplish or reddish brown sand, consisting of large and small grains of cassiterite, about 48½ per cent., small particles of tourmaline, and a little quartz and fluorspar. All the material passes through a 30-mesh sieve, 2 per cent. remains on 60-mesh, 4 per cent. on a 90-mesh, 3 per cent. on 120-mesh, while 91 per cent. passes through a sieve of 120-mesh. As a whole the material is clean and the grains of fairly uniform size, although there are a good many fine grains. The photograph is very similar to that shown in Fig. 2, Plate XXII., but the grains are of more uniform size. The "tailings" from the buddle are not shown in the plate. The material is a gritty dark purplish or reddish brown sand, the grains of which vary considerably in size, from the fineness of dust to large particles. Some grains are $\frac{1}{16}$ of an inch across. In sizing by sieves, 8 per cent. remains on 30-mesh sieve, 30 per cent. on 60-mesh, 20 per cent. on 90-mesh, 5 per cent. on 120-mesh, while 37 per cent. passes through a sieve of 120-mesh. Oxide of iron from burnt pyrites is abundant. Fine grains of cassiterite are present, and a few larger grains of the same mineral. Quartz, fluorspar, and tourmaline are also present in abundance. About 11 per cent. of cassiterite is present.

The "head" from the buddle is treated in "kieves." The concentrate from the kieves is shown in Fig. 3, Plate XXII. In sizing by sieves 1 per

cent. remains on 30-mesh. 6 per cent. on 60-mesh, 9 per cent. on 90-mesh, 5 per cent. on 120-mesh, while 79 per cent. passes 120-mesh. Some of the grains are as large as $\frac{1}{16}$ of an inch across. In appearance it is a very fine dark purplish or reddish brown sand containing abundant cassiterite (62 per cent.). There is also tourmaline, and a little fluorspar and quartz. Oxide of iron, in opaque grains of various sizes, is likewise present. The product is a fairly clean one, and is known as "crop tin." Fig. 4, Plate XXII., is a sample of the skimmings from the kieves. In appearance it is a very fine dark purplish or reddish brown sand containing 8 per cent. of cassiterite. There is oxide of iron, tourmaline, fluorspar, and quartz. It practically all passes through a sieve of 120-mesh, a few grains only being arrested by the 90 and 120 sieves.

The tailings from the Frue vanners, containing slime tin, are shown in Fig. 5, Plate XXII. It is a fine light grey gritty sand. In sizing by sieves 9 per cent. remains on 30-mesh, 50 per cent. on 60-mesh, 15 per cent. on 90-mesh, 6 per cent. on 120-mesh, while 20 per cent. passes 120. Under the microscope it is seen to consist of very fine, almost dusty, particles of quartz, with a little tourmaline and chlorite. Large grains are also present, and consist mainly of quartz. The quartz contains dusty inclusions which under high powers of the microscope are seen to be fluid cavities. About $\frac{1}{4}$ per cent. of cassiterite is present.

The tailings from the Frue vanners are led into an upward current separator which yields two products—slimes and rough waste. The sample shown in Fig. 7, Plate XXII., is from the slimes. Seen in bulk it is a dirty grey clayey-looking powder. It all passes through a sieve of 120-mesh except some mica which is arrested. Under the microscope the material consists of small grains of quartz, a little fluorspar and chlorite, and some tourmaline and extremely fine dusty fragments of these and other minerals. About ·8 per cent. of cassiterite is present. As a whole, although very fine grained, the material is not of uniform size. Fig. 6, Plate XXII., shows a sample of the rough waste from the upward current separator. It is a clean grey speckled sand, containing grains of quartz, mica, tourmaline, fluorspar, chlorite, and some small grains of cassiterite (·2 per cent.) Although on the whole it is rather coarse-grained, the grains vary considerably in size. In sizing by sieves 2·5 per cent. remains on 30-mesh, 30 per cent. remains on 60-mesh, 26·5 per cent. remains on 90-mesh, 12 per cent. on 120-mesh, while 29 per cent. passes through a sieve of 120-mesh. It is this material which is passed through launders or strips, so that the heavier portions may settle and be once more treated on the vanners after being pulverised. The slime is calcined, treated on ragging frames and revolving tables. The concentrates from the revolving tables are shown in Fig. 8, Plate XXII. It is a fine dark grey powder consisting of small grains of fairly uniform size, all of which pass through 120-mesh sieve. Tourmaline is abundant, and in addition to cassiterite, of which there is 9 per cent., there is also a little fluorspar, chlorite, quartz, and hæmatite. The material is known as "slime tin." The waste from the ragging frames and revolving tables is a loose clayey-looking dirty grey powder, all of which, except the mica, passes through a sieve of 120-mesh. Under the microscope the particles are seen to be of irregular size. The larger particles consist of quartz, a little tourmaline, chlorite, and fluorspar. The smaller particles are fine dust of the same minerals. About ·5 per cent. of cassiterite is present.

In the examination of this series of products, the most striking point is the general great variety in the sizes of the grains in each sample of the material, and it is probable that if the materials were sized before treatment losses would be considerably reduced.

A significant result of the examination of the products by the microscope is that from each of the operations in the production of "crop" or "slime" tin, the "wastes" exhibit a greater variety as regards the size of their constituent grains than do the grains in the concentrates. From this it may be inferred that grains of cassiterite, which are less than the average size of the grains in the concentrates from any of the operations, tend to be lost in the tailings of the subsequent operation.

If the samples obtained are to be relied on as being good average products, then the concentrates from the Frue vanners contained a little over $\frac{5}{6}$ (84 per

cent.) of the total amount of cassiterite in the pulp coming from the stamps. That is to say that every 100 tons of pulp coming from the stamps contains $1\frac{1}{2}$ tons of cassiterite, of which 1·26 tons pass into 6 tons of concentrates coming from the vanners containing 21 per cent. cassiterite; and ·24 tons pass into 94 tons of tailings, containing, therefore, about $\frac{1}{4}$ per cent. cassiterite. In the subsequent operations resulting in the production of "crop" tin, the amount of cassiterite present in the tailings becomes greater and greater as the concentrates get richer and richer. Unless these tailings are very carefully treated great losses are liable to occur. In the operations leading to the production of "fine" or "slime" tin, the materials worked with are poor, so that as large a proportion of loss is not to be expected, but with the rapid handling of a great deal of stuff a considerable portion of the cassiterite originally in the tailings is unavoidably lost.

A less extensive series of microscope slides showing the products from different operations was prepared for materials obtained from Dolcoath, which is a mine yielding almost exclusively tin ore. Fig. 1, Plate XXIII., is a sample of the pulp as it comes from the stamps. It is a fine brownish sand containing grains of various sizes. In testing the sizes of the grains by sieves $1\frac{1}{2}$ per cent. remains on 30-mesh, 14 per cent. on 60-mesh, 22 per cent. on 90-mesh, 7·5 per cent. on 120-mesh, while 55 per cent. passes through a sieve of 120-mesh. The particles consist of quartz, much of which contains many inclusions of acicular blue tourmaline; blue tourmaline, a little chlorite, some fluorspar, and colourless and brown cassiterite. It is an exceptionally rich sample containing 11 per cent. of cassiterite. Some of the large opaque grains consist of quartz crowded with tourmaline needles associated with the remains of some decomposed ferruginous mineral. There are many very minute grains.

The next sample, Fig. 2, Plate XXIII., is that of the concentrates from the Frue vanners. In general appearance it is a very fine greyish brown sand, consisting of variously sized grains of quartz, some of which contain much included ferruginous material and tourmaline; a little fluorspar, tourmaline, chlorite, and an abundance of cassiterite ($27\frac{1}{2}$ per cent.), some of which is in a very fine state of division. Tests by sieving show that 8 per cent. of the material remains on a 30-mesh sieve, 19 per cent. on a 60-mesh, 9 per cent. on a 90-mesh, 4 per cent. on a 120-mesh, while 60 per cent. passes through a sieve of 120-mesh.

The concentrates from the Frue vanners are calcined and treated in an upward current separator. The coarse material so obtained goes to a pit buddle. The sample shown in Fig. 3, Plate XXIII., is from the head of the buddle. In general appearance it is a coarse dark brown sand, consisting of grains of quartz with inclusions of tourmaline and fluid cavities. There is also fluorspar and cassiterite in abundance (50 per cent.). Some of the materials are coarse and others fine, and as a whole the sizes of the grains are very varied. They are greatly stained with iron oxide. Trials by sieving show that 4 per cent. remains on 30-mesh, 51 per cent. on 60-mesh, 29 per cent. on 90-mesh, 5 per cent. on 120-mesh, while 11 per cent. passes through a sieve of 120-mesh. This material is passed on to a Wilfley table, and the resulting concentrate is sold as "crop tin," which contains 78 per cent. cassiterite (61·5 per cent. metallic tin). It is a mixed coarse and fine sand of a brown colour. The grains are mainly cassiterite, but there is some ferruginous material. In sieving 1 per cent. remains on 30-mesh sieve, 39 per cent. on 60-mesh, 24 per cent. on 90-mesh, 9 per cent. on 120-mesh, while 27 per cent. passes through a sieve of 120-mesh.

The overflow from the upward current separator is treated in a buddle. Fig. 4, Plate XXIII., represents the material from the head of the buddle. It is a fine brown powder containing $3\frac{1}{2}$ per cent. cassiterite. There is much oxide of iron, and some fluorspar, quartz, and a little tourmaline. The product is a good one, consisting of uniformly sized grains nearly all of which pass through a sieve of 120-mesh.

The next, Fig. 5, Plate XXIII., is a sample of the concentrate from the Acme table upon which the stuff last described was treated. It is an impalpable light brown powder containing 78 per cent. cassiterite, with a little oxide of iron and tourmaline. This material is sold as "fine tin."

It all passes through a sieve of 120-mesh. The tailings from the Frue vanners are a reddish brown powder, consisting of grains of quartz with many dusty ferruginous inclusions; and very fine particles of tourmaline, quartz, chlorite, and ferruginous minerals. Cassiterite is present only in small quantity (·85 per cent.), but after a series of operations it is separated and ultimately sold as "slime" tin. The material is very fine, nearly all passing sieve of 120-mesh. The use of the upward current separator for treating the calcined concentrates from the vanners appears to be most important and could not be dispensed with.

From a general standpoint, the most striking feature in the microscopical diagrams of the various products is the want of uniformity in the sizes of the grains, which, except in a few cases, points to a defect in the usual methods employed. If the tin grains were themselves of uniform size this objection would not be of much importance, but a large proportion of the tin occurs in very minute particles, and it is a rule in all dressing appliances to separate this "slime" from the coarser-grained "crop" tin as soon as possible, and subject each to a separate series of operations. No convenient method has yet been discovered for accurately sizing the grains, so that a certain amount of loss is inevitable, but a saving on the present system might be made by the judicious employment of upward current separators in which the minerals could be classified according to the relative speeds with which they fall through water. Each product might then be treated by itself; the "crop" on Frue vanners or Buss tables, and the slimes on Luhrig vanners or on revolving tables. A fine degree of stamping is essential, but the production of an excessive amount of slime might be obviated by the use of wire screens, so that the pulp could pass away from the stamps as soon as possible after crushing.

A few samples were obtained from the large tin stream works near Reskudinnick, called Kieve Mill. The waste material from the dressing floors of the mines is discharged into the Red River, and successively treated by a number of stream work companies situated at various points along the stream. The material under examination has therefore already been treated by stream works before it arrived at Kieve Mill. The river as it approaches the works is divided into two parts by a wooden partition, and arranged in such a way that the water can be made to flow through one part or the other by means of sluices. This is done so that the amount of water passing at different times of the year may be regulated to a steady flow. By means of stops, or transverse partitions in the river, the coarse particles of sand being carried along in the current are arrested and sink in the bottom of the river just above the works. The water carrying slime flows on into long pits, any one or more of which can be used or not as desired (Plate XXI.). Here the slime is allowed to settle. Fig. 6, Plate XXIII., is a sample of the sands which have settled in the river just above the works. In appearance it is a clean speckled sand containing from $\frac{3}{4}$ to $1\frac{1}{4}$ per cent. cassiterite. Under the microscope the grains are seen to be both large and small. In testing the sizes of the grains by sieves 3 per cent. remains on 30-mesh sieve, 53 per cent. on 60-mesh, 22 per cent. on 90-mesh, 7 per cent. on 120-mesh, while 15 per cent. passes a sieve of 120-mesh. The larger grains are subangular or rounded. Quartz occurs in large grains with many fluid cavities, and contains other inclusions, such as tourmaline; fluorspar, chlorite, and a little tourmaline and oxide of iron are also present. The large opaque minerals seen in the plate are principally quartz crowded with tourmaline needles (peach). Some of it is bright green chlorite and mica. There is also some brown staining which appears as half-tones in the largest fragment. The dusty-looking inclusions are mainly fluid cavities in quartz.

Fig. 7, Plate XXIII., is a sample of the slime from the settling pits. Seen in bulk, the slime is a brown or reddish brown impalpable powder, and contains ·5 per cent. cassiterite. Under the microscope most of the particles are extremely small. Tourmaline is plentiful, chlorite and fluorspar are also present. Limonite and hæmatite occur in particles and as staining. Most of the grains are too fine to be readily identified in the slide, and all pass through a sieve of 120-mesh. The slime is stirred up in a current of water and passed on to ragging frames, of which there are a great number.

(Plate XXIV.). The concentrate is settled in pits, and passed over another series of frames into settling pits, after which it is treated on revolving tables of the Bartle type. Then it proceeds to buddles. The slime tin so collected is similar in appearance to Fig. 5, Plate XXIII., but is even finer, and consists of an impalpable dark purplish brown powder. The grains are clean and sharply angled, of uniform size, and all pass through a sieve of 120-mesh. Cassiterite (40 per cent.) with tourmaline, much hæmatite, and a little fluorspar appear to be the most abundant minerals.

The coarse sands which settled in the stream above the works (Fig. 6, Plate XXIII.) are washed down periodically by a strong current of water into "strips" or troughs, in which transverse wooden partitions or "stops" are fixed at intervals. The lighter sands flow out of the strips, but the heavier sink and are dug out periodically. Fig. 8, Plate XXIII., is a sample of the material which was deposited in the "strips." It is a clean dark speckled sand, consisting of quartz, chlorite, oxides of iron (limonite and hæmatite), tourmaline, fluorspar, and some chalybite. There are a few grains of cassiterite (about 1 per cent.). This material is pulverised in a rotary mill and worked over on revolving frames and buddles. In this way particles of cassiterite which were locked up in grains of quartz., &c., are liberated and extracted. Tested by means of sieves it is found that 3 per cent. remains on a 30-mesh, 60 per cent. on a 60-mesh, 20 per cent. on a 90-mesh, 7 per cent. on a 120-mesh, while 10 per cent. pass through 120-mesh. A sample of the sands from the river, about $\frac{3}{4}$ of a mile below the works at Kieve Mill, is a clean dark speckled sand, consisting of quartz with fluid cavities, and tourmaline inclusions, fluorspar, tourmaline, chlorite, a little chalybite, and some iron oxide. Cassiterite is seen in several cases actually adhering to larger fragments of other minerals. The sample contains about $1\frac{1}{2}$ per cent. of tin. Tested by sieves 3 per cent. remains on 30-mesh, 70 per cent. on 60-mesh, 19 per cent. on 90-mesh, 4 per cent. on 120-mesh, while $4\frac{1}{2}$ per cent. pass through a sieve of 120-mesh.

MINERAL STATISTICS.*

* Compiled from statistics contained in:—*Tr. R.G.S. Corn.*, vol. i., 1818, &c., for years 1815 to 1832 (copper only). *Grylls's Annual Mining Sheets* (Redruth) for years 1833 to 1836 (copper only). *Tr. R.G.S. Corn.*, vol. v. (Henwood), p. 466, for year 1838 (copper only). *Geol. Rep. Corn., Devon, and West Somerset* (De la Beche), 1839, for year 1837 (tin only). *Mining Review*, 1839 and 1840, for tin ore in 1838 and 1839. *Mem. Geol. Survey*, vol. ii., 1848, for years 1845 to 1847 (copper only). *Records Royal School of Mines*, vol. i., part iv., 1853, for years 1848 to 1852 (copper and lead from 1848 to 1852; tin in 1852). *Mem. Geol. Survey* (Mineral Statistics), 1853 to 1881 (for all minerals, the output of zinc, mundic, arsenic, nickel and cobalt, umber and ochre, iron, &c., commencing in 1854; public ticketings, stannary returns, and inspectors' reports). *General Report and Statistics, part iii., Output*, issued by the Home Office, all minerals for years from 1882 to 1904. Under the heading of Remarks the output of copper ore and copper for a stated interval prior to 1857 is obtained from the *Records of Mining and Metallurgy*, by John Arthur Phillips and John Darlington. These figures fill in to a certain extent the lucuna in the official statistics, *i.e.*, the years 1837 to 1844, and represent the sales at public ticketings in Cornwall. The returns prior to 1882 are approximate only, so that figures representing the total outputs of minerals for the years mentioned must be regarded as general relative measures of the actual output and not as being strictly accurate. Not only do the annual returns in the early statistical tables differ according as the returns were made by the stannaries, public ticketings, or inspectors' reports, &c., but much of the ore was sold by private contract and the sales never recorded. In early years it was customary for the smelters to demand 21 cwts. to the ton, while in a number of other ways the tables are rendered inaccurate. Statistics are not obtainable for the years 1837 to 1844 (with the exception of copper in 1838 and black tin in 1837). Another point to which attention should be called is error arising from the ambiguity caused by different mines bearing the same name, and in such cases it is frequently almost impossible to determine from which mines certain annual outputs refer. Such names for instance as "Prosper," "Providence," "Virgin," "Fortune," are common names for mines. Under the heading of Remarks the figures for the period up to 1856 are those given by Phillips and Darlington. The output since 1857 is also given so as to complete the statistics furnished by them.

Output of Copper Ore and Copper from 1815 to 1836, and 1845 to 1905; and of Black Tin from 1852 to 1905.

Name of Mine.	Total yield and largest amount raised in one year.			Remarks.
	Black tin.	Copper ore.	Copper.	
	Tons.	Tons.	Tons.	
Balmynheer Mine	350	...	...	Yielded between 1868 and 1880.
	84	...	...	
Baldhu - -	2	...	...	In 1880.
Barncoose -	...	206	26	In 1819, 1820, and 1821 (Phillips and Darlington).
Basset, Wheal -	14,178	94,200	8,100	From 1815 to 1827; 1832 to 1836, and from 1851 to 1905.
	794	7,713	680	
Basset, Consols	...	330	18	From 1859 to 1861.
Bassett and Grylls	2,900	...	...	From 1861 to 1875.
	314	...	...	
Bell Tin Mine	10	...	...	In 1874.
Bellvean Mine	4	...	...	In 1879 and 1880.
Bissoe Bridge -	44	...	...	In 1838 and 1839.
Bissoe Pool -	$\frac{1}{10}$	...	...	In 1896.
Bolenowe -	...	138	5	In 1842 (according to Phillips and Darlington).
Boscawen and Wheal Andrew	1	69	3	In 1832, 1833, and 1834, and in 1894.
				5,091 tons of copper ore containing 273 tons of copper were sold between 1831 and 1845.
Boys, Wheal -	5	22	1½	Between 1873 and 1878.
Brewer, Wheal	...	1,420	130	Between 1845 and 1852.
	...	1,142	78	5,373 tons of copper ore containing 328 tons of copper were sold between 1842 and 1853.
Buckets, Wheal	...	2,700	170	Between 1846 and 1849.
	...	1,281	85	
Buller, Wheal -	1,410	98,700	14,340	Between 1845 and 1875.
	167	13,560	850	
Buller and Beauchamp	...	41,700	2,600	Between 1823 and 1828.
	...	6,539	443	1832 to 1836 and in 1838.
Burra Burra Mine	...	260	12	In 1862 and 1863, and in 1875 and 1876.
Calvadnack -	1,150	...	...	Between 1854 and 1875.
	138	...	...	
Camborne Consols	170	1,180	80	Between 1853 and 1891.
	...	189	15	
Camborne Vean	350	37,500	2,770	Between 1816 and 1832, and 1845 and 1855.
	77	3,297	229	
				Between 1815 and 1856, 29,932 tons of ore containing 2,259 tons of copper were sold.
Carn Brea -	29,600	158,200	11,300	From 1833 to 1836, in 1838, and between 1845 and 1895; tin in 1837, 1838, and 1839, and since 1852.
	1,195	10,430	1,050	

Name of Mine.	Total yield and largest amount raised in one year.			Remarks.
	Black tin.	Copper ore.	Copper.	
	Tons.	Tons.	Tons.	
Carn Brea—*cont.*	...	...	...	161,593 tons of ore containing 12,039 tons of copper were produced between 1833 and 1856. From 1857 to 1895, 75,900 tons of ore containing 5,858 tons of copper.
	...	...	...	
Carn Brea and Tincroft United	6,587	8,454	363	Between 1896 and 1905.
	696	1,533	75	
Carn Camborne	115	6,310	305	Between 1862 and 1879.
	42	1,247	62	
Cardrew Consols	...	15,900	850	Between 1827 and 1836.
	...	1,594	107	17,143 tons of ore containing 1,141 tons of copper were sold between 1826 and 1838.
Carharrack	$1\frac{1}{4}$	...	...	In 1885.
Carvannel	...	2,500	180	Between 1851 and 1856, 1,782 tons of ore containing 139 tons of copper were sold. From 1857 to 1859, 700 tons of ore containing 40 tons of copper.
	...	474	37	
Cathedral Mine (Consols)	$1\frac{3}{4}$	585	40	From 1874 to 1881.
	...	312	21	
Chance, Wheal (Gwennap)	...	14,800	1,530	Between 1815 and 1828.
	...	1,323	156	
Chance Consols	...	3,998	337	Between 1826 and 1827 (Phillips and Darlington).
Clarence, Wheal	...	67	2	In 1835, 1865, and 1866.
Clifford Amalgamated	365	144,300	9,140	Between 1833 to 1836 and between 1845 and 1876. Between 1835 and 1856 "Wheal Clifford" sold 9,495 tons of ore containing 725 tons of copper. Between 1857 and 1872, 135,400 tons of ore containing 8,480 tons of copper.
	...	15,180	965	
Clifford United	4	...	...	Between 1893 and 1895.
Clowance, Wheal	...	7,580	612	Between 1815 and 1824.
	...	1,461	118	
Clyjah and Wentworth	$3\frac{1}{2}$	2,500	155	Between 1854 and 1862.
	...	874	50	
Combellack and Mengearn	136	...	...	Between 1878 and 1883.
	39	...	...	
Comford, Wheal (and North Tresavean)	125	1,570	85	Between 1845 and 1885.
	26	128	19	
Condurrow	2,030	30,200	2,020	From 1845 to 1876.

Name of Mine.	Total yield and largest amount raised in one year.			Remarks.
	Black Tin.	Copper ore.	Copper.	
	Tons.	Tons.	Tons.	
Condnrrow—*cont.*	404	1,941	128	20,095 tons of ore containing 1,500 tons of copper were sold between 1818 and 1856. From 1857 to 1865, 10,400 tons of ore containing 543 tons of copper.
Consolidated Mines	32 ...	331,300 15,523	27,000 1,530	From 1815 to 1836, in 1838, and from 1845 to 1857; some black tin in 1837 and since 1852. 441,286 tons of ore containing 37,402 tons of copper sold between 1815 and 1856. In 1857, 1,105 tons of ore containing 59 tons of copper.
Cook's Kitchen	8,510 349	38,800 2,120	2,100 161	From 1815 to 1836, in 1838, and from 1845 to 1897; some tin in 1837, 1838, and 1839, and since 1852. 43,606 tons of ore containing 2,484 tons of copper sold between 1815 and 1856.
Copper Bottom	...	265	25	In 1835, 1836, and in 1860. 1,436 tons of ore containing 121 tons of copper were produced between 1836 and 1851.
Crane Mine (and Bejawsa)	... ...	1,770 326	160 28	In 1851, 1852, and 1853 and since 1862.
Creegbraws and Penkevil	1,320 134	14,530 2,062	875 119	Between 1815 and 1832, and 1845 and 1902. 15,496 tons of copper ore containing 1,022 tons of copper sold between 1815 and 1856.
Crenver, Abraham and Oatfield	960 804	112,050 11,073	7,740 797	Between 1815 and 1832, and 1845 to 1870.
Cupid, Wheal	6	44	2	From 1855 to 1862.
Courtis, Wheal	... ...	2,290 354	120 20	In 1838 and from 1864 to 1869. 2,341 tons of ore containing 142 tons of copper were sold between 1838 and 1844.
Damsel, Wheal	77 20	37,600 2,919	3,300 304	From 1815 to 1836, in 1838, and 1845 to 1872.

Name of Mine.	Total yield and largest amount raised in one year. Black Tin.	Copper ore.	Copper.	Remarks.
	Tons.	Tons.	Tons.	
Dolcoath (Wh. Harriet, &c.)	77,300 2,555	230,300 9,807	16,100 794	From 1815 to 1836, in 1838, and from 1845 to 1905. From 1815 to 1856, 241,522 tons of ore containing 17,478 tons of copper. From 1857 to 1874, 6,300 tons containing 375 tons of copper.
Druid, Wheal	... ...	214 176	28 22	In 1815 and 1816.
East Wheal Basset	87 ...	15,050 2,039	1,520 308	From 1826 to 1832, 1845 to 1878.
East Basset and Grylls	$5\frac{3}{4}$	...	...	In 1864 and 1865.
East Carn Brea	6 ...	22,080 4,021	1,365 230	Since 1859.
East Wheal Crofty	41 37	54,000 6,173	3,500 483	From 1832 to 1836, in 1838, and between 1845 and 1855. 100,952 tons of ore containing 7,280 tons of copper sold between 1832 and 1854.
East Wheal Damsel	$\frac{1}{2}$	...	...	In 1891.
East Downs (and Silverwell)	$\frac{1}{10}$	85	4	From 1863 to 1899.
East Wheal Ellen	... ...	231 198	11 10	Between 1859 and 1861.
East Grenville	23	327	16	In 1875.
East Wheal Lovell	2,405 232	... ...	... ...	Between 1859 and 1891.
East Pool and Wheal Agar	38,490	88,300	5,010	In 1836, 1837, and 1838, and from 1845 to 1905. 38,780 tons of ore containing 2,918 tons of copper were sold from East Pool between 1835 and 1856. From 1857 to 1903, 54,310 tons containing 2,769 tons of copper.
East Wheal Seton	$1\frac{1}{2}$	1,720	122	Between 1847 and 1875.
East Wheal Tolgus	57 ...	17,140 713	1,260 36	Between 1847 and 1863.
East Treskerby	...	36	3	Between 1863 and 1865.
East Trumpet	20	...	...	Between 1868 and 1871.
East Wheal Vor	32	...	...	In 1856 and 1857.
East Wheal Uny	32 ...	352 156	32 14	Between 1881 and 1884.
Ellen United, Wheal	... ...	12,600 1,541	750 77	From 1834 to 1836, in 1838, and between 1845 and 1865.

Name of Mine.	Total yield and largest amount raised in one year.			Remarks.
	Black Tin.	Copper ore.	Copper.	
	Tons.	Tons.	Tons.	
Ellen United, Wheal—*cont.*	... ...	... ...	... ...	20,025 tons of ore containing 1,365 tons of copper were sold between 1826 and 1854. From 1855 to 1865, 3,290 tons of ore containing 159 tons of copper.
Emily Henrietta, Wheal	... ...	1,820 627	136 45	Between 1862 and 1871.
Emma, Wheal -	... ...	530 323	27 14	In 1875 and 1876.
Enys, Wheal (Enys Mines)	259 78	... ...	... ...	Between 1853 and 1859.
Falmouth and Sperries, Wheal (and Falmouth Consols)	... ...	1,150 207	40 10	In 1832, 1833, 1834, and between 1860 and 1872. Between 1819 and 1833, 1,808 tons of ore were sold containing 87 tons of copper.
Fanny, Wheal	... ...	8,450 1,740	780 166	From 1815 to 1822.
Fursden, Wheal	2	...	...	In 1860.
Garlidna United (and Polengrean)	174	3		Between 1861 and 1880.
Gerry, Wheal -	...	187	8	In 1824 and 1825 (Phillips and Darlington).
Gorland, Wheal	15 ...	38,500 2,959	2,850 243	Between 1815 and 1836; in 1838 and 1845, and 1878.
Grambler, Wheal	50	11	1	In 1835 and in 1872.
Grambler and St. Aubyn	4 ...	8,440 1,490	740 112	From 1845 to 1868. 7,280 tons of ore containing 569 tons of copper were sold between 1843 and 1856. From 1857 to 1868, 2,690 tons containing 297 tons of copper.
Great Wheal Baddern	30 13	... ...	... ...	Between 1848 and 1858.
Great Briggan	... ...	1,390 506	96 31	Between 1861 and 1866.
Great Wheal Busy (Chacewater Mine)	1,860 284	92,100 4,108	4,600 314	Between 1815 and 1836, 1845 and 1897, and in 1904. 33,486 tons of ore containing 1,669 tons of copper were sold between 1823 and 1856. From 1857 to 1866, 35,660 tons containing 1,432 tons of copper.

Name of Mine.	Total yield and largest amount raised in one year.			Remarks.
	Black Tin.	Copper ore.	Copper.	
	Tons.	Tons.	Tons.	
Gustavus Mine	...	89	6	Between 1852 and 1864.
Great Wheal Lovell	64	...	...	Between 1871 and 1876.
Great North Downs	14 ...	9,110 2,513	640 182	Between 1862 and 1897.
Great North Tolgus (Wheal Elizabeth)	...	4,120	215	From 1832 to 1834 and between 1845 and 1862.
Great South Tolgus	101 66	16,500 3,297	1,100 256	Between 1854 and 1869.
Great Wheal Vor	9,620 847	2,270 743	205 75	Between 1853 and 1877. Copper from 1822 to 1826, 1832 and 1836, and in 1838. 4,300 tons of ore containing 330 tons of copper were sold between 1821 and 1842.
Grenville, Wheal	4,635 1,006	2,330 738	190 67	Between 1860 and 1905.
Hallenbeagle (Boscawen) and Croft Gothal	⅓ ...	10,020 2,879	510 152	From 1834 to 1836, in 1838, and between 1845 and 1859. 30,580 tons of ore containing 1,803 tons of copper were produced between 1835 and 1846.
Harmony and Montague	3 ...	22,450 2,309	2,400 350	Between 1820 and 1834, and from 1845 to 1880. Between 1819 and 1844, 29,407 tons of ore containing 2,950 tons of copper were sold.
Henry, Wheal	... ...	1,860 503	150 39	In 1835, and between 1815 and 1847.
Hope, Wheal	1 ...	4,910 1,011	491 118	Between 1826 and 1832, and 1845 and 1866. 5,584 tons of ore containing 534 tons of copper were sold between 1824 and 1837.
Jane, Wheal	3,830 344	740 286	30 14	Between 1847 to 1895.
Jewell, Wheal	9 ...	38,100 4,061	3,015 526	From 1815 to 1836, and in 1838. 58,160 tons of ore containing 5,222 tons of copper were sold between 1815 and 1853.
Killifreth	4,060 259	681 128	56 11	Between 1859 and 1904.
King Edward (part of South Condurrow)	3	...	...	In 1904

Name of Mine.	Total yield and largest amount raised in one year.			Remarks.
	Black Tin.	Copper ore.	Copper.	
	Tons.	Tons.	Tons.	
Lovell, Wheal -	750	...	...	Between 1852 and 1863.
	132	...	...	
Lovell, The, Mine	577	...	...	Between 1874 and 1876.
	64	...	...	
Lovell Consols	69	...	...	In 1871.
Lydia, Wheal -	...	3,900	234	Between 1845 and 1847.
	...	2,267	136	
Maid, Wheal (and Carharrack)	...	27,800	2,015	Between 1821 and 1836, 1838, and from 1845 to 1852.
	...	4,281	362	23,552 tons of ore containing 1,542 tons of copper were sold between 1820 and 1852.
Maria, Wheal -	...	41,150	4,540	Between 1845 and 1847.
	...	15,684	1,578	
Mary, Wheal -	184	7,670	460	Between 1827 and 1836, 1845 and 1872.
	...	1,596	119	
Mary Consols, Wheal	...	2,370	200	Between 1830 and 1832, 1845 and 1849.
	...	721	66	
Medlyn Moor Mine	80	...	...	Between 1874 and 1880.
	29	...	...	
Metal and Flow, Wheal	540	...	...	Between 1885 and 1901.
	54	...	...	
Mount Carbis-	77	...	...	Between 1882 and 1885.
Moyle, Wheal -	44	285	6	Between 1861 and 1863.
Music, Wheal	...	4,600	750	Between 1815 to 1825, and in 1832, 1833.
	...	1,046	176	
Nancegollan -	6	...	...	In 1854.
Nancekuke -	40	...	...	Since 1851.
Nangiles and Wheal Andrew	106	3,020	206	Between 1845 and 1876, and in 1905.
	...	459	34	
New Cook's Kitchen	470	2,820	390	Between 1877 and 1891.
	179	522	40	
New Dolcoath	45	220	18	Between 1872 and 1875.
	...	112	10	
New Wheal Frances	12	...	...	In 1861 and 1862.
New Wheal Hender	6	155	12	Between 1861 and 1863.
	...	128	11	
New Wheal Lovell	375	59	3	Between 1865 and 1874.
	95	...	...	
New Wheal Seton	...	5	½	In 1863.
New South Ellen	...	25	2	In 1862.
New Treleigh Consols (and New Treleigh)	...	2,820	140	Between 1859 and 1869.
	...	485	22	
New Trevennen	3	3	¼	In 1861.
New Trumpet Consols (Lovell United)	22	560	89	Between 1875 and 1888.

Name of Mine.	Total yield and largest amount raised in one year.			Remarks.
	Black Tin.	Copper ore.	Copper.	
	Tons.	Tons.	Tons.	
New Wheal Vor and East Wheal Metal	125	...	...	Between 1859 and 1861.
	69	...	...	
Nelson, Wheal	...	6	$\frac{1}{3}$	In 1863.
North Basset -	165	27,800	2,200	Between 1846 and 1866.
	38	5,104	552	
North Wheal Buller	...	280	22	Between 1822 and 1852 (Phillips and Darlington).
North Wheal Busy	5	1,020	60	Between 1854 and 1861.
	...	264	18	
North Busy United	220	750	45	Between 1875 and 1887.
	...	253	14	
North Wheal Crofty	1,610	9,170	535	Between 1854 and 1899.
	...	1,582	100	
North Wheal Damsel	$2\frac{3}{4}$	580	45	Between 1852 and 1854.
	...	322	24	
North Dolcoath	...	43	3	Since 1862.
North Downs -	12	22,800	1,890	From 1815 to 1836, and from 1845 to 1871.
	...	1,492	132	Tin in 1837 and since 1852. 19,348 tons of ore containing 1,600 tons of copper were sold between 1815 and 1855. From 1856 to 1871, 10,500 tons of ore containing 855 tons of copper.
North Wheal Frances	...	440	30	Between 1857 and 1862 .
North Wheal Grambler	...	2,670	210	Between 1859 and 1867.
	...	511	45	
North Hallenbeagle	...	61	$4\frac{1}{2}$	In 1862 and 1863.
North Wheal Jane	70	...	...	Between 1861 and 1875.
	19	...	...	
North Lovell -	9	...	...	Between 1871 and 1874.
North Metal -	8	...	...	In 1883 and 1884.
North Penstruthal	60	...	...	Between 1880 and 1886.
North Pool -	$1\frac{1}{2}$	47,670	2,860	Between 1845 and 1867.
	...	6,447	433	
North Roskear (and Wheal Crofty)	1,440	132,070	9,710	Between 1819 and 1836, 1845 and 1874.
	190	7,419	265	151,800 tons of ore containing 11,850 tons of copper were sold from North Roskear between 1816 and 1856. From 1857 to 1874, 15,600 tons containing 1,155 tons of copper.
North Treskerby	150	19,270	1,290	Between 1859 and 1882.
	12	2,323	146	

Name of Mine.	Total yield and largest amount raised in one year.			Remarks.
	Black Tin.	Copper ore.	Copper.	
	Tons.	Tons.	Tons.	
Old Wheal Basset	... ...	570 160	36 10	Between 1854 and 1860.
Old Wheal Tolgus	...	28	...	In 1859.
Old Tolgus United	8	145	...	In 1859.
Pedn an Drea (and Sparnon Consols)	7,700 367	1,090 240	57 18	Between 1854 and 1891.
Pendarves United	2,660 476	575 ...	34 ...	Between 1866 and 1881.
Pendarves and St. Aubyn	...	125	10	In 1854.
Penhale Wheal Vor	85 36	... ...	... ...	Between 1866 and 1869.
Pennance -	... ...	590 105	35 10	Between 1866 and 1872.
Penstruthal (and Penstruthal Consols)	370 ...	59,500 8,385	2,740 672	Between 1825 and 1836, 1845 and 1879. Between 1819 and 1846, 51,830 tons of ore containing 3,073 tons of copper were sold.
Perseverance Mine (and Wentworth and Copper Hill)	19 ...	10,870 1,285	732 86	Between 1856 and 1877.
Peevor, Wheal	3,280 649	5 ...	1/5 ...	Between 1872 and 1889.
Pink, Wheal -	1/20 ...	1,830 408	120 30	Between 1815 and 1833, 1845 and 1855. 1,881 tons of ore containing 158 tons of copper were sold between 1821 and 1850.
Plenty, Wheal-	...	155	11	In 1838 (Phillips and Darlington).
Polcrebo - -	102 30	... ...	... ...	Between 1884 and 1890.
Poldice - -	1,525 307	15,300 2,485	965 153	In 1838 and between 1845 and 1873. Tin in 1837, 1838 and 1839, and since 1852. 2,992 tons of ore containing 208 tons of copper were sold between 1815 and 1852. From 1868 to 1873, 3,635 tons of ore containing 231 tons of copper.
Poldice and East Wheal Maid	1/2	...	...	In 1891.

Name of Mine.	Total yield and largest amount raised in one year.			Remarks.
	Black Tin.	Copper ore.	Copper.	
	Tons.	Tons.	Tons.	
Polgine, Wheal	...	495	41	In 1836 and 1837 (Phillips and Darlington).
Polhigey Moor and Polhigey New Mine	28	...	...	Between 1864 and 1874.
Prosper, Wheal	86	311	7	Between 1862 and 1870.
	39	194	3	
Prosper United	830	22,490	1,020	Between 1863 and 1872.
	191	4,523	234	
Prussia, Wheal (and Cardrew United)	206	13	¾	Between 1874 and 1883.
Raven, Wheal -	...	1,447	117	Between 1825 and 1828.
	...	565	45	
Redruth Consols	...	740	50	Between 1836 and 1843 (Phillips and Darlington).
Rose, Wheal	18	12,820	834	Between 1862 and 1872.
	...	3,717	223	
Roskear - -	...	23	1	In 1864 and 1865.
St. Andrew -	...	370	15	In 1845.
St. Aubyn United	43	1,380	91	Between 1871 and 1892.
St. Day United (St. Day Manor—Poldice, Unity Wood, Wheal Maid, and Wheal Gorland)	3,280	22,900	1,360	Between 1852 and 1893.
	480	3,175	230	9,728 tons of ore containing 658 tons of copper were sold between 1852 and 1856. From 1857 to 1867, 11,170 tons containing 602 tons of copper.
Scorrier Consols	15	...	...	In 1874 and 1875.
Seton, Wheal -	990	113,050	7,080	In 1838 and from 1845 to 1877.
	...	5,402	451	Largest output in 1847.
Seymour, Wheal	...	675	43	In 1815 and 1816 (Wheal Ann), and in 1877 and 1878 (Wheal Seymour).
South Basset -	...	37,100	3,020	From 1833 to 1836, in 1838, and between 1845 and 1861.
	...	3,390	267	94,649 tons of ore containing 7,200 tons of copper were sold between 1825 and 1856.
South Buller -	...	2,220	211	In 1822 and from 1863 to 1865.
South Buller and Beauchamp	...	127,796	8,554	Between 1821 and 1856, according to Phillips and Darlington.

Name of Mine.	Total yield and largest amount raised in one year.			Remarks.
	Black Tin.	Copper ore.	Copper.	
	Tons.	Tons.	Tons.	
South Carn Brea	845 129	3,550 628	312 87	Between 1856 and 1877.
South Condurrow	11,430 861	1,060 247	106 30	Between 1864 and 1902.
South Wheal Crofty	5,080 ...	33,700 3,208	9,000 164	Between 1854 and 1905.
South Dolcoath	... ...	1,800 273	145 19	In 1832 and 1834 and between 1859 and 1876.
South Wheal Ellen	... ...	2,600 747	115 38	Between 1856 and 1861.
South Wheal Frances	9,710 728	66,590 6,463	5,660 505	Between 1845 and 1895. 33,522 tons of ore containing 3,252 tons of copper were sold between 1844 and 1856. From 1857 to 1878, 34,500 tons of ore containing 2,503 tons of copper.
South Wheal Lovell	81	...	...	Between 1860 and 1868.
South Penstruthal	$\frac{1}{3}$	...	...	In 1880.
South Roskear	175 ...	21,600 1,464	1,400 113	Between 1825 and 1836, in 1838, and from 1845 to 1881. 37,807 tons of ore containing 2,904 tons of copper were sold between 1821 and 1850.
South Tolcarne and West Condurrow	230 ...	1,300 543	114 50	Between 1859 and 1883.
South Tolgus (South Wheal Tolgus)	14 ...	36,770 2,839	2,850 224	Between 1848 and 1865.
South Towan	... ...	12,900 2,088	720 137	Between 1819 and 1827, 1832 to 1836, and in 1838.
South Wendron Mine	...	7	...	Between 1875 and 1878.
Sparnon, Wheal	1½ ...	1,710 460	141 33	Between 1815 and 1821.
Sparrow, Wheal	...	1,510	65	From 1832 to 1836, in 1838, and in 1865. 2,227 tons of ore containing 147 tons of copper were sold between 1829 and 1841.
Sperries, Wheal	1	2,275	84	Between 1830 and 1832, 1845 and 1855. 3,146 tons of ore containing 117 tons of copper were sold between 1829 and 1831.
Spinster, Wheal	... ...	4,500 702	400 65	Between 1815 and 1829.

Name of Mine.	Total yield and largest amount raised in one year.			Remarks.
	Black Tin.	Copper ore.	Copper.	
	Tons.	Tons.	Tons.	
Squire, Wheal	...	20,000	1,506	Between 1817 and 1825, and in 1852 and 1853.
	...	4,705	412	20,082 tons of ore containing 1,724 tons of copper were sold between 1816 and 1853.
Stray Park -	590	19,100	1,190	Between 1828 and 1836, 1838, and 1845 to 1867.
	88	2,344	164	Between 1829 and 1856, 38,610 tons of ore containing 2,748 tons of copper were sold.
Stray Park and Camborne Vean	...	1,330	100	In 1827.
Susan, Wheal -	...	566	30	In 1822 and 1825.
	...	360	20	
Tehidy, Wheal	...	1,725	120	From 1834 to 1836, and between 1855 and 1861.
	...	339	31	2,021 tons of ore containing 180 tons of copper were sold between 1835 and 1856. Between 1857 and 1861, 560 tons of ore containing 41 tons of copper.
Tincroft - -	22,700	104,500	5,940	Black tin in 1837, 1838, and 1839, and since 1852; between 1815 and 1836, 1845 and 1895.
	829	9,559	515	94,210 tons of ore containing 5,346 tons of copper were sold between 1815 and 1856. From 1857 to 1895, 18.560 tons containing 1,106 tons of copper.
Ting Tang -	...	40,240	3,270	Between 1816 and 1835 and from 1845 to 1847.
	...	4,310	307	
Tolcarne - -	99	5,630	303	Between 1860 and 1870.
	97	1,065	56	
Tolgullow United (and West Poldice)	570	20	3	Between 1882 and 1903.
	171	...	...	
Tolgus, Wheal	...	30,750	2,855	Between 1825 and 1836 and in 1838.
	...	5,286	620	33,531 tons of ore containing 3,450 tons of copper were sold between 1820 and 1839.
Trannack, Wheal	...	8,200	540	In 1822, from 1832 to 1835, and in 1864.
	...	1,448	122	
Trannack and Bosence	...	255	23	In 1851 and 1852.

Name of Mine.	Total yield and largest amount raised in one year.			Remarks.
	Black Tin.	Copper ore.	Copper.	
	Tons.	Tons.	Tons.	
Trefusis, Wheal	205	350	23	Between 1853 and 1863.
	51	196	13	
Tregajorran -	...	1,660	202	Between 1815 and 1822.
	...	398	48	
Tregothnan Consols	...	1,417	63	Between 1840 and 1844.
Treleigh	...	13,420	1,030	In 1835 and 1836, and between 1845 and 1856.
Consols	...	2,308	217	21,900 tons of ore containing 1,420 tons of copper were sold between 1838 and 1855.
Treleighwood	533	37	3	Between 1874 and 1878.
Mine	131	...	...	
Tresavean -	106	151,700	9,940	Between 1815 and 1836, in 1838, and from 1845 to 1879.
	...	8,178	894	163,260 tons of ore containing 15,702 tons of copper were sold between 1815 and 1856. Between 1857 and 1871, 4,460 tons of ore containing 167 tons of copper.
Tresavean	...	2,130	176	Between 1845 and 1848.
Barrier	...	874	83	2,830 tons of ore containing 244 tons of copper were sold between 1844 and 1848.
Treskerby -	9	32,510	2,945	Between 1815 and 1822 and in 1832.
	...	4,696	467	
Treskerby and Chance Consolidated	...	18,500	1,675	Between 1823 and 1827.
	...	3,915	356	
Trethellan -	...	12,690	580	In 1838, and between 1845 and 1860.
	...	2,612	143	35,545 tons of ore containing 1,922 tons of copper were sold between 1837 and 1856.
Trevennen and Tremenheere	730	37	4	Between 1854 and 1876.
Treviskey -	1	17,790	1,550	Between 1845 and 1855.
	...	2,884	285	17,946 tons of ore containing 1,568 tons of copper were sold between 1844 and 1855.
Trevoole - -	...	3,400	141	In 1827 and from 1859 to 1862.
	...	640	25	
Treworlis -	412	690	36	Between 1860 and 1873 and in 1882.
	52	407	22	
Trumpet	4,510	4	$\frac{3}{4}$	Between 1854 and 1880.
Consols	298	...	...	
Trumpet United	12	...	...	Between 1863 and 1865

Name of Mine.	Total yield and largest amount raised in one year.			Remarks.
	Black Tin.	Copper ore.	Copper.	
	Tons.	Tons.	Tons.	
Tryphena -	31	74	16	In 1847 and 1848 and in 1862.
United Hills -	26 ...	26,110 3,390	1,490 209	From 1822 to 1836, 1845 to 1847. 54,473 tons of ore containing 3,582 tons of copper were sold between 1826 and 1847.
United Mines (Gwennap United)	250 77	284,400 14,374	19,800 1,012	Some tin in 1837 and since 1852; between 1815 and 1836, 1845 and 1861; in 1880 and 1881, and from 1893 to 1901. 304,530 tons of ore containing 22,680 tons of copper were sold between 1815 and 1856. Between 1857 and 1861, 43,110 tons of ore containing 2,063 tons of copper.
Unity and Unity Consols	40 22	... ...	... ...	Between 1852 and 1855.
Unity and Poldice	... ...	83,100 6,897	6,890 554	Between 1815 and 1832.
Unity Wood, Wheal, and Wheal Union	570 128	21,620 858	1,290 56	Between 1815 and 1836, in 1838, and since 1853; tin in 1837 and since 1852. 32,760 tons of ore containing 2,465 tons of copper were sold between 1823 and 1842.
Uny, Wheal	7,660 423	2,860 353	155 27	Between 1853 and 1893. Between 1826 and 1856, 755 tons of ore yielding 39 tons of copper were sold. Between 1857 and 1866, 2,070 tons of ore containing 112 tons of copper.
Virgin, Wheal (part of Clifford Amalgamated)	... ...	7,420 946	415 72	In 1815 and from 1834 to 1836, and from 1845 to 1847. 22,974 tons of ore containing 1,656 tons of copper were sold between 1821 and 1847.
Vyvian, Wheal	92 26	4,140 378	235 22	From 1832 to 1836, in 1838, and between 1845 and 1864. 8,277 tons of ore containing 500 tons of copper were sold between 1827 and 1856. Between 1857 and 1864, 200 tons of ore containing 10 tons of copper.

Name of Mine.	Total yield and largest amount raised in one year.			Remarks.
	Black Tin.	Copper ore.	Copper.	
	Tons.	Tons.	Tons.	
Wellington, Wheal	...	2,830	213	Between 1822 and 1827 (Phillips and Darlington).
Wendron Consols	2,390 269	48 ...	8 ...	Between 1854 and 1869.
Wendron United Mines	27	...	...	In 1853 and in 1875, 1876.
West Basset	10,150 1,000	101,500 7,673	7,155 532	Between 1852 and 1890.
West Buller	$\frac{1}{8}$	1,170	125	In 1849.
West Carvannel	...	110	...	In 1859.
West Clifford	...	73	3	In 1865.
West Wheal Damsel	18 ...	29,150 2,166	1,560 117	Between 1852 and 1874.
West Wheal Frances	8,940	28	$1\frac{1}{2}$	Between 1854 and 1896.
West Wheal Gorland	68	70	4	Between 1871 and 1876.
West Wheal Grenville	...	11	...	In 1859.
West Wheal Jane	410 58	50 ...	... ...	Between 1854 and 1889.
West Wheal Jewell	8 ...	6,620 1,883	410 113	In 1832 and 1833 and between 1845 and 1852; tin 1837 and in 1852. Between 1831 and 1852, 12,578 tons of ore containing 858 tons of copper were sold.
West Wheal Peevor	1,200	...	...	Between 1879 and 1887.
West Pink	130	280	15	In 1832, 1833, 1834. and 1835.
West Poldice (and West Poldice United)	650 158	1,152 336	90 28	From 1832 to 1836; between 1874 and 1884; tin in 1837 and since 1852.
West Wheal Seton	3,720 299	114,450 7,155	9,300 520	Between 1848 and 1890.
West Wheal Squire	... ...	3,390 1,148	383 139	Between 1818 and 1822.
West Stray Park	2 ...	3,635 485	275 37	Between 1854 and 1868.
West Tolgus	$\frac{4}{40}$	47,700	4,020	From 1832 to 1836 and between 1861 and 1883.
West Tresavean	5	...	...	In 1837.
West Wheal Towan	520 114	... ...	... ...	Between 1853 and 1882.
West Trethellan	... ...	1,390 435	63 20	Between 1845 and 1850.
West Wheal Virgin	...	90	$4\frac{1}{2}$	In 1818.
West Wheal Ver	$\frac{1}{2}$	...	...	In 1878.

Output of Minerals, other than Tin and Copper, from 1848 to 1905.

Name of Mine.	Total yield and largest amount raised in one year.								Other products.
	Lead ore.	Lead.	Silver.	Zinc ore.	Iron pyrites and sulphur ores.	Crude and refined arsenic.	Gossan. Oxide of iron.	Ochre and umber.	
	Tons.	Tons.	Ozs.	Tons.	Tons.	Tons.	Tons.	Tons.	
Basset Consols	14	9	144	...	...	...	...	...	
Basset Valley	...	...	...	120	...	...	...	...	In 1879.
Bissoe Pool -	...	...	...	...	...	4	...	...	
Boscawen -	...	...	...	33	...	...	...	...	139 tons arsenical pyrites since 1864.
Buller, Wheal	...	...	...	...	43	...	...	...	In 1857.
Burra Burra Mine	3	2¼	55	320	...	...	...	...	
Camborne Consols	...	...	...	...	4	200	...	...	
Camborne Vean	...	...	...	...	...	30	...	...	
Carn Brea -	... ...	... ...	... ...	... ...	... ...	4,140 302	... ...	... ...	16 tons arsenical pyrites.
Carn Brea and Tincroft United	... ...	... ...	... ...	... ...	... ...	3,142 421	... ...	... ...	390 tons of wolfram (239 highest yield in one year).
Carn Camborne	...	...	...	...	...	72	...	...	40 tons of arsenical pyrites.
Carvannel -	...	...	...	...	4½	...	...	...	
Clifford Amalgamated -	... ...	... ...	... ...	1,011 974	5,550 550	7 ...	... ...	... ...	
Comford, Wheal (and North Tresavean)	...	...	...	...	...	13	...	...	
Concord, Wheal	60	36	...	...	...	...	...	...	Between 1845 and 1847.
Condurrow -	...	...	...	...	6½	34	...	...	
Consolidated Mines	...	...	...	60	1,050	7½	...	...	
Cook's Kitchen	...	...	...	...	...	120	...	...	222 tons arsenical pyrites.

Name of Mine.	Total yield and largest amount raised in one year.								Other products.
	Lead ore.	Lead.	Silver.	Zinc ore.	Iron pyrites and sulphur ores.	Crude and refined arsenic.	Gossan. Oxide of iron.	Ochre and umber.	
	Tons.	Tons.	Ozs.	Tons.	Tons.	Tons.	Tons.	Tons.	
Crane Mine -	2	$1\frac{1}{4}$	13	...	...	...	...	...	
Creegbraws and Penkevil	...	...	...	$3\frac{1}{2}$	160	50	...	106	4 tons arsenical pyrites.
Crenver, Abraham, and Oatfield	$4\frac{1}{2}$	$3\frac{1}{4}$	15	...	744	$\frac{1}{4}$	...	...	
	...	...	...	...	296	...	...	...	
Cupid, Wheal	...	...	...	...	...	...	...	...	22 tons fluorspar.
Courtis, Wheal	...	...	...	3	...	...	...	...	
Damsel, Wheal	...	...	...	...	...	...	...	...	114 tons of fluorspar.
Daniell, Wheal	...	...	...	...	...	...	...	15	In 1872.
Dolcoath -	...	...	(?)	12	...	1,550	...	...	634 tons arsenical pyrites (276 highest output in one year). 2 cwts. bismuth ore.
	...	...	...	...	...	102	...	...	
East Downs (and Silverwell)	...	...	...	...	...	...	...	...	107 tons of arsenical pyrites.
East Wheal Falmouth	413	320	17,100	487	...	...	...	...	Between 1856 and 1861.
East Pool and Wheal Agar	...	...	...	...	15	21290	...	...	1,860 tons of wolfram, 100 tons of sodium tungstate, $\frac{1}{2}$ ton uranium ore, $4\frac{1}{2}$ tons cobalt ore, 4 tons bismuth ore, 1 ton of ore containing nickel, cobalt, and bismuth.
East Wheal Seton	...	...	...	...	125	...	...	...	

Name of Mine.	Total yield and largest amount raised in one year.								Other products.
	Lead ore.	Lead.	Silver.	Zinc ore.	Iron pyrites and sulphur ores.	Crude and refined arsenic.	Gossan. Oxide of iron.	Ochre and umber.	
	Tons.	Tons.	Ozs.	Tons.	Tons.	Tons.	Tons.	Tons.	
East Wheal Tolgus	...	...	...	11	47	...	...	...	
Emily Henrietta, Wheal	...	...	...	12	12	...	...	...	
Falmouth and Sperries, Wheal	60	41	353	180	47,800	...	10474	...	
	...	...	...	...	9,045	...	3,005	...	
Fortune, Wheal	...	...	...	...	...	...	...	...	$3\frac{1}{2}$ tons silver ore in 1880.
Gorland, Wheal	...	...	...	...	...	18	...	...	$20\frac{1}{2}$ tons of wolfram.
Great Wheal Baddern	3,160	2,230	37,611	202	362	...	...	60	14 tons arsenical pyrites.
	628	447	9,400	...	...	...	...	...	
Great Wheal Busy	$3\frac{1}{2}$	$2\frac{1}{5}$	44	...	148	155	38	...	20,720tons of arsenical pyrites (5,778 largest output in one year).
Great North Downs	...	...	...	...	...	...	...	...	373 tons arsenical pyrites (248 tons largest output in one year).
Great South Tolgus	...	...	...	2	...	15	...	...	
Great Wheal Vor	...	...	...	...	...	41	...	...	
Hope, Wheal	141	100	1,968	$1\frac{1}{6}$	...	...	...	...	
Jane, Wheal	203	138	2,921	586	33,340	243	3,666	100	88 tons arsenical pyrites.
	...	...	...	102	5,118	...	1,149	...	
Jewell, Wheal	20	14	...	...	...	...	...	...	
Killifreth	...	...	...	...	17	360	...	6	12 tons arsenical pyrites.
Nancekuke	747	505	13,709	...	...	...	...	...	
Nangiles and Wheal Andrew	...	...	...	146	2,770	163	16	62	
	...	...	...	...	1,481	...	...	...	
New Treleigh Consols (and New Treleigh)	...	...	...	$7\frac{1}{4}$	...	...	...	...	

Name of Mine.	Total yield and largest amount raised in one year.								Other products.
	Lead ore.	Lead.	Silver.	Zinc ore.	Iron pyrites and sulphur ores.	Crude and refined arsenic.	Gossan. Oxide of iron.	Ochre and umber.	
	Tons.	Tons.	Ozs.	Tons.	Tons.	Tons.	Tons.	Tons.	
North Wheal Busy	...	...	...	415	92	...	...	...	
	...	...	...	382	...	...	...	...	
North Busy United	$\frac{1}{2}$	...	...	584	172	...	...	...	24 tons of arsenical pyrites.
	...	...	...	310	...	...	...	...	
North Wheal Crofty	...	...	...	...	$5\frac{1}{2}$	1,470	...	...	992 tons arsenical pyrites (545 tons highest output in one year).
	...	...	...	...	...	380	...	...	
North Dolcoath	...	...	...	...	...	...	...	...	228 tons of silver ore. In 1858, $2\frac{1}{2}$ tons of silver chloride.
North Wheal Jane	...	...	...	...	370	...	340	...	
	...	...	...	...	166	...	249	...	
North Pool -	...	...	...	23	...	17	...	...	
North Roskear	...	...	...	6	...	1,340	...	...	
North Treskerby	...	...	...	...	10	16	...	...	96 tons arsenical pyrites.
Old Wheal Basset	...	...	...	...	14	...	...	...	
Old Tolgus United	...	...	...	5	...	...	...	...	
Pedn an Drea (and Sparnon Consols)	...	...	...	...	...	974	...	...	
	...	...	...	...	...	75	...	...	
Pendarves United	...	...	...	...	...	56	...	...	
Perseverance Mine (and Wentworth and Copper Hill)	...	...	...	...	...	...	...	...	119 tons fluorspar.
Peevor, Wheal	...	...	...	...	7	...	...	...	12 tons arsenical pyrites.
Poldice -	$\frac{1}{3}$	$\frac{1}{4}$	...	12	51	873	...	321	1,822 tons arsenical pyrites.
	...	...	...	...	...	216	...	...	
Prosper, Wheal	...	...	...	...	...	209	...	...	
Prosper United	68	36	200	...	200	1,160	...	...	

Name of Mine.	Total yield and largest amount raised in one year.								Other products.
	Lead ore.	Lead.	Silver.	Zinc ore.	Iron pyrites and sulphur ores.	Crude and refined arsenic.	Gossan. Oxide of iron.	Ochre and umber.	
	Tons.	Tons.	Ozs.	Tons.	Tons.	Tons.	Tons.	Tons.	
St. Aubyn United	...	...	...	...	...	...	...	...	172 tons fluorspar.
St. Day United (St. Day Manor—Poldice, Unity Wood, Wheal Maid, Wheal Gorland)	...	...	...	...	...	...	38	...	124 tons arsenical pyrites; 49 tons fluorspar.
Seton, Wheal	... ...	... ...	... ...	19 ...	25 ...	1,900 155	... ...	... ...	10 tons of fluorspar.
Seymour, Wheal	...	...	...	25	...	...	...	...	
South Carn Brea	...	...	...	...	...	4	...	...	
South Condurrow	...	...	...	...	...	4	...	...	
South Wheal Crofty	...	...	...	...	1,110	3,251	...	...	19 tons of wolfram.
South Wheal Ellen	4	3	...	137	42	...	...	...	
South Garras	1,930 506	1,025 243	71,930 23,455	... ...	11 ...	... ...	... ...	... ...	Between 1855 and 1860.
South Roskear	... ...	... ...	... ...	35 ...	... ...	655 257	... ...	... ...	
South Wheal Seton	...	...	...	...	...	92	...	...	In 1872.
South Tolgus (South Wheal Tolgus)	½	⅓	...	8	77	...	...	...	
Stray Park	...	...	...	...	42	...	...	...	
Swanpool	895 706	179 141	3,579 ...	... ...	... ...	... ...	... ...	... ...	In 1859 and 1860.
Tincroft	22 ...	15 ...	... ...	... ...	... ...	3,286 553	... ...	... ...	
Tolgullow United (and West Poldice)	...	...	...	...	...	222	...	184	152 tons arsenical pyrites.
Trannack, Wheal	...	...	...	3½	...	...	...	...	
Tresavean United Mines	4½	3	... ...	... 271 ...	312 1,290 996	... 158 ...	... ...	... ...	
Unity and Unity Consols	⅓	⅕	...	...	...	243	...	...	

Name of Mine.	Total yield and largest amount raised in one year. Lead ore.	Lead.	Silver.	Zinc ore.	Iron pyrites and sulphur ores.	Crude and refined arsenic.	Gossan. Oxide of iron.	Ochre and umber.	Other products.
	Tons.	Tons.	Ozs.	Tons.	Tons.	Tons.	Tons.	Tons.	
Unity Wood and Wheal Union	1½	1 1/10	...	...	21	129	...	...	
Uny, Wheal -	...	...	...	...	6	...	...	50	
West Wheal Damsel	...	...	...	...	...	...	...	...	638 tons fluorspar (332 tons highest yield in one year.)
West Wheal Damsel and Cupid	...	...	...	...	...	...	...	...	256 tons fluorspar.
West Wheal Jane	26	19	158	390	27,170	382	207	...	
	...	...	...	76	4,300	...	...	...	
West Wheal Peevor	...	...	...	...	...	20	...	...	
West Poldice (and West Poldice United)	...	...	...	...	6	...	...	...	
West Wheal Seton	...	...	...	...	24	4,026	...	...	
West Tolgus	...	...	...	97	...	...	...	...	
West Wheal Towan	...	...	...	1½	200	...	...	...	

Stream Works, &c.—Tin Ore obtained from Mine Refuse, Foreshores, &c.

Red River and River from Carn Brea and Tincroft.

Year.	Dressed tin ore.		Metallic tin obtainable by smelting.		Value.
	Tons	cwts.	Tons	cwts.	£
1882 -	1,252	0	726	0	53,306
1883 -	1,103	16	541	0	42,350
1884 - -	1,154	2	635	0	35,016
1885 - -	1,142	18	628	10	37,218
1886 - -	1,104	3	...		48,177
1887 - -	1,010	10	...		46,486
1888 -	1,446	6	867	0	63,182
1889 - -	911	0	...		43,392
1890 - -	1,302	0	...		52,080
1891 - -	880	0	...		33,704
1892 - -	905	4	...		34,780

River from Wheal Basset, West Basset, Wheal Uny, &c., to Portreath.

Year.	Dressed tin ore.		Metallic tin obtainable by smelting.		Value.
	Tons	cwts.	Tons	cwts.	£
1882 - -	265	0	148	8	11,309
1883 - -	255	10	125	0	9,200
1884 - -	171	17	93	0	6,039
1885 - -	184	9	103	0	6,887
1886 - -	170	10	...		7,679
1887 - -	207	1	...		9,690
1888 - -	206	3	123	0	9,852
1889 - -	278	0	...		7,619
1890 - -	428	0	...		17,126
1891 - -	330	0	...		10,469
1892 - -	261	2	...		10,016

*Total Annual Production of Tin Ore of Cornwall from Abandoned Mine-heaps, Waste from Mine Dressing Floors, Stream Works, &c.**

Year.	Black tin.		Metallic tin.	Value.
	Tons	cwts.	Tons.	£
1882 - -	1,654	0	950	...
1883 -	1,439	0	709	...
1884 - -	1,415	0	778	...
1885 -	1,395	0	770	...
1886 - -	1,337	0	802	...
1887 - -	1,278	0	767	...
1888 - -	1,742	0	1,045	...
1889 - -	1,272	0	763	...
1890 -	1,796	0	1,078	...
1891 -	1,301	0	780	...
1892 - -	1,282	0	769	...
1893 - -	1,228	0	737	45,601
1894 - -	1,300	0	780	29,075
1895 -	1,000	0	400	25,000
1896 - -	716	0	322	15,603
1897 -	877	14	395	22,057
1898 - -	746	0	335	20,020
1899 -	709	0	319	32,088
1900 - -	761	0	342	39,030
1901 - -	687	0	309	30,805
1902 - -	825	0	350	40,049
1903 - -	839	0	356	42,136
1904 - -	721	0	334	37,387
1905 - -	818	18	377	46,824

Refuse Heaps of Abandoned Mines, "Old Men's" Burrows, &c.

Year.	Dressed tin.		Metallic tin.		Value.
	Tons	cwts.	Tons	cwts.	£
1882 - - -	17	17	10	6	870
1883 - -	8	14	4	18	483
1892 - - -	86	19	56	10	4,364
1893 - - -	64	16	42	2	2,952
1894 - - -	72	5	46	19	2,544

* Mainly from the mine tailings flowing down the rivers above mentioned.

Index Tables of the Mines.

The following table contains an alphabetical list of the mines included in this sheet, together with the parishes in which they occur. The mines now working are the Basset Mines, Carn Brea and Tincroft United, Cook's Kitchen, South Crofty, Dolcoath, East Pool and Wheal Agar :—

Mine.	Parish.
Abraham Consols	Crowan
Agar, Wheal	Illogan
Ale and Cakes	Gwennap
Andrew, Wheal	Gwennap and Kea
Ann, Wheal	Kenwyn Wendron
Annie, Wheal	Gwinear
Baddern (Baddon), Wheal	Kea
Baldhu	Kea
Bal Ding	Wendron
Balmynheer Mine	Wendron
Banns, Wheal	St. Agnes
Barberry, Wheal	Redruth
Barncoose Mine	Illogan
Basset, Wheal	Illogan
Basset and Grylls	Wendron
Beauchamp, Wheal	Gwennap
Bell and Lannarth	Gwennap
Bellvean Mine	Gwennap
Bissoe Pool	Gwennap
Bodilly Consols	Wendron
Bolenowe	Camborne
Boscawen Mine	Kenwyn
Boys, Wheal	Redruth
Bramble, Wheal	Sithney
Brewer, Wheal	Gwennap
Briggan, Wheal	Redruth
Britannia, Wheal	Gwennap
Brook, Wheal	Gwinear
Buckets, Wheal	Redruth
Buller and Basset United	Wendron
Buller, Wheal	Redruth
Burra Burra Mine	Kenwyn
Busy, Wheal	Kenwyn
Calvadnack Mine	Wendron
Camborne Consols	Camborne
Camborne Vean	Camborne
Captain, Wheal	Redruth
Carbona Mine	Crowan
Cardrew Consols	Redruth
Carharrack	Gwennap
Carleen Mine	Breage
Carnarthen	Illogan
Carn Brea	Illogan
Carn Camborne	Camborne
Carnemow	Camborne
Carnmeal Mine	Breage
Carnkie	Illogan
Carqueen	Gwennap
Carvennal	Gwennap
Cathedral Mine	Gwennap
Chacewater Mine	Kenwyn
Chance, Wheal	Gwennap Redruth
Charles, Wheal	St. Agnes
Christopher, Wheal	St. Agnes
Clarence, Wheal	Illogan
Clifford, Wheal	Gwennap
Clifford Amalgamated	Gwennap
Clinton, Wheal	Gwennap
Clinton, Wheal	Mylor
Clowance, Wheal	Crowan
Clowance Wood Mine	Crowan
Clyjah and Wentworth	Redruth
Combellack Mine	Wendron
Comford, Wheal	Gwennap
Concord, Wheal	St. Agnes
Cook's Kitchen	Illogan
Copper Hill	Redruth Camborne
Copper Bottom	Crowan
Copper Tankard	Camborne
Cornwall Mine	St. Agnes
Courtis, Wheal	Crowan
Crack Crowder Mine	Gwinear
Crane and Bejawsa	Camborne
Creegbraws	Kenwyn
Crenver and Wheal Abraham	Crowan
Crofty, Wheal	Camborne
Crowan and Wendron Mines	Wendron
Cudy, Wheal	Wendron
Cupboard Hill Mines	Gwennap
Cupid, Wheal	Gwennap
Cusvey	Gwennap
Damsel, Wheal	Gwennap
Daniell, Wheal	Kenwyn
Derrick, Wheal	Redruth
Dolcoath Mine	Camborne
Dopps Mine	Redruth
Dream, Wheal	Wendron
Druid, Wheal	Illogan
Drym Mine	Crowan
Duchy, Wheal	Illogan Wendron
Dudnance	Illogan
East Wheal Abraham	Crowan
East Ale and Cakes	Gwennap

Mine.	Parish.
East Wheal Basset	Gwennap, Illogan, Redruth
East Wheal Buller	Gwennap
East Carn Brea	Redruth
East Wheal Chance	Kenwyn
East Wheal Crofty	Illogan
East Wheal Damsel	Gwennap
East Downs Mine -	St. Agnes
East Wheal Ellen -	St. Agnes
East Wheal Falmouth - -	Kea, Kenwyn
East Wheal Fortune - -	Sithney
East Grenville -	Camborne
East Wheal Lovell	Wendron
East Wheal Music -	St. Agnes
East Pool Mine	Illogan
East Rosewarne -	Gwinear
East Wheal Seton -	Camborne, Illogan
East Wheal Sparnon - - -	Gwennap
East Wheal Tolgus	Redruth
East Towan -	St. Agnes
East Tresavean -	Camborne
East Treskerby	St. Agnes
East Trumpet Mine	Wendron
East Wheal Virgin	Gwennap
East Wheal Vor	Sithney
Edgecumbe, Wheal	Gwennap
Elizabeth, Wheal -	Illogan
Ellen, Wheal - -	Illogan, St. Agnes
Emily Henrietta, Wheal -	Illogan
Emma, Wheal -	Breage
Enys, Wheal - -	Wendron
Falmouth and Sperries - -	Kea
Fancy, Wheal -	St. Agnes
Fanny, Wheal -	Illogan
Fire, Wheal - -	Illogan
Forest, Wheal -	Illogan
Fortune, Wheal	Gwennap, Breage, Illogan
Foster, Wheal	Wendron
Fox Hole Sett -	Illogan
Frances, Wheal -	Camborne
Friendship, Wheal	Gwennap
Fursden, Wheal	Sithney
Garlidna - -	Wendron
Gernick - -	Crowan
Gerry, Wheal -	Camborne
Gilbert, Wheal -	Redruth
Gilly Mine -	Camborne
Gine, Wheal -	Camborne
Girl, Wheal - -	Gwennap
Gons, Wheal - -	Camborne
Good Success Mine	Redruth
Gorland, Wheal	Gwennap

Mine.	Parish.
Grambler, Wheal -	Gwennap
Great Condurrow -	Camborne
Great Consolidated	Gwennap
Great Wheal Baddern (Baddon) -	Kea
Great Wheal Busy	Kenwyn
Great East Lovell	Wendron
Great Wheal Fortune - -	Breage
Great Drym Consols - - -	Crowan
Great Wheal Lovell - -	Wendron
Great Wheal Metal	Breage
Great North Downs - -	Redruth
Great North Tolgus - -	Illogan
Great St. Vincent -	Illogan
Great South Tolgus - -	Redruth
Great Wheal Vor -	Breage
Grenville, Wheal -	Camborne
Grillis, Wheal	Illogan
Gustavus Mine	Camborne
Gwinear Consols -	Gwinear
Hallenbeagle Mine	Kenwyn
Hangman's Barrow	Crowan
Harmony, Wheal	Redruth
Harriet, Wheal -	Sithney, Camborne
Hatchet, Wheal -	Camborne
Hawk, Wheal	Redruth
Hender, Wheal -	Crowan
Henry, Wheal -	Kenwyn, Gwennap
Hope, Wheal	Kea, Gwennap
Illogan Mine -	Illogan
Jane, Wheal - -	Kea
Jewell, Wheal -	Gwennap
Kellivose Mine -	Camborne
Killifreth Mine	Kenwyn
King Edward Mine	Camborne
Knight, Wheal -	Illogan, Camborne
Lily, Wheal - -	Redruth
Little North Downs - -	Redruth
Longclose Mine -	Illogan
Louisa, Wheal -	Redruth
Lovell, Wheal -	Wendron
Lower Bolenowe Mine - - -	Camborne
Lushington, Wheal	Illogan
Lydia, Wheal -	Illogan
Maid, Wheal	Gwennap
Margaret, Wheal -	Gwinear

Mine.	Parish.
Maria, Wheal	Redruth
Mary, Wheal	Redruth
Medlyn Moor Mine	Wendron
Mengearn	Wendron
Messar, Wheal	Redruth
Metal, Wheal	Breage
Millet, Wheal	Crowan
Montague, Wheal	Redruth
Mount, Wheal	Sithney
Mount Carbis	Redruth
Music, Wheal	St. Agnes
Nancegollan	Crowan
Nancekuke, see South Wheal Ellen	Illogan
Nangiles	Kea
Nelson, Wheal	Camborne Crowan
New Burra Burra	Kenwyn
New Clifford	Gwennap
New Cook's Kitchen	Illogan
New Dolcoath	Camborne
New Wheal Frances	Crowan
New Hallenbeagle	Kenwyn
New Hendra Mine	Breage
New Wheal Lovell	Wendron
New North Pool	Illogan
New Rosewarne Mine	Gwinear
New Wheal Seton	Camborne
New Treleigh	Redruth
New Trevenen	Wendron
New Trumpet Consols	Wendron
New Vor and Metal United	Sithney
New Wendron Mine	Wendron
North Wheal Basset	St. Agnes Illogan
North Briggan	Redruth
North Buller	Redruth
North Wheal Busy	Kenwyn
North Crofty	Illogan
North Wheal Damsel	Gwennap
North Dolcoath	Camborne
North Downs	Redruth
North Wheal Frances	Illogan
North Grambler	Redruth
North Hallenbeagle	St. Agnes
North Wheal Jane	Kenwyn
North Lovell Mine	Wendron
North Metal Mine	Sithney
North Wheal Metal	Breage
North Penstruthal	Gwennap
North Pool Mine	Illogan
North Prospidnick	Sithney

Mine.	Parish.
North Roskear	Camborne Illogan
North Treskerby	St. Agnes
North Trewan Mine	Redruth
North Wheal Vor	Breage
Old Wheal Basset	Illogan
Old Wheal Jewell	Gwennap
Old Wheal Lovell	Wendron
Old Pool Mine	Illogan
Old Trevenen Mine	Wendron
Park an chy Mine	Gwennap
Pedn an Drea	Redruth
Peevor, Wheal	Redruth
Pellor, Wheal Metal	Breage
Pendarves Consols	Camborne
Penhaldarva	Kenwyn
Penhale Mine	Breage
Penhale Wheal Vor	Breage
Penkevil	Kenwyn
Pennance Mine	Gwennap
Penrose, Wheal	Budock
Penstruthal Mine	Gwennap
Perseverance Mine	Redruth
Pink, Wheal	Gwennap Redruth
Plenty, Wheal	Redruth
Polcrebo	Crowan
Poldice Mine	Gwennap
Poldory	Gwennap
Poldown	Breage
Polhigey Mine	Wendron
Polgine Mine	Camborne
Polladras Mine	Breage
Prosper, Wheal	Kenwyn
Providence, Wheal	Illogan
Prussia, Wheal	Redruth
Quick, Wheal	Gwennap
Raven, Wheal	Redruth
Releath Mine	Wendron
Retanna Hill	Wendron
Rose, Wheal	St. Agnes
Rose Ann Mine	St. Agnes
Roselidden Mine	Wendron
Roskrow United	St. Gluvias
St. Aubyn United	Gwennap Redruth
St. Day United	Gwennap
Sarah, Wheal	Crowan
Scorrier Consols	St. Agnes
Scorrier Old Mine	Kenwyn
Seton, Wheal	Camborne
Seymour, Wheal	Kenwyn
Silver Hill	Perranarworthal
Sithney, Wheal	Sithney
Sithney Carnmeal Mine	Sithney

Mine.	Parish.
Sithney Wheal Metal	Sithney
Sithney Wheal Vor	Sithney
South Wheal Basset	Illogan
South Carn Brea	Illogan
South Wheal Clinton	Gwennap
South Condurrow	Camborne
South Crenver	Crowan
South Crofty	Illogan
South Dolcoath	Illogan
South Wheal Ellen	St. Agnes
South Wheal Frances	Illogan
South Garras	Kenwyn
South Gorland	Gwennap
South Great Tolgus	Redruth
South Wheal Grenville	Camborne
South Wheal Hawk	Redruth
South Lovell	Wendron
South Penstruthal	Gwennap
South Roskear	Camborne
South Wheal Seton	Camborne
South Tincroft	Illogan
South Tolcarne	Camborne
South Wheal Tolgus	Redruth
South Wheal Towan	St. Agnes
South Tresavean	Perranarworthal
South Wendron Mine	Constantine Wendron
Sparnon, Wheal	Redruth
Sparrow, Wheal	Illogan
Sperries, Wheal	Kea
Spinster, Wheal	Gwennap
Squire, Wheal	Gwennap
Susan, Wheal	Camborne
Swanpool	Falmouth
Tallack, Wheal	St. Agnes
Tehidy, Wheal	Illogan
Tincroft	Illogan
Ting Tang Mine	Gwennap
Todpool Mine	Gwennap Kenwyn
Tolans Mine	Redruth
Tolcarn Mine	Gwennap
Tolgullow	Kenwyn
Tolgus, Wheal	Redruth
Tolgus United Mine	Redruth
Towan, Wheal	Illogan St. Agnes
Towan Consols	St. Agnes
Trannack, Wheal	Sithney
Trefula Mine	Redruth
Trefusis, Wheal	Gwennap
Tregajorran	Illogan
Tregonebris	Wendron
Trelawney, Wheal	Redruth
Treleigh Consols	Redruth
Treleighwood Mine	Redruth
Trelusback Mine	Stithians
Tremenheere	Wendron
Trenear Mine	Wendron
Trenithick Mine	St. Agnes
Trenithick Wood Mine	Wendron
Tresavean Mine	Gwennap Redruth
Treskerby Mine	Gwennap
Tretharrup	Gwennap
Trethellan	Gwennap
Trevarno Mine	Sithney
Trevenson	Illogan
Trevenen Bal	Wendron
Treviskey	Gwennap
Trevoole	Crowan
Treworlis Mine	Wendron
Trewirgie Downs	Redruth
Trumpet Consols	Wendron
Tryphena, Wheal	Camborne
Tywarnhayle Mines	St. Agnes
Union, Wheal	Redruth Wendron
Union Mines	Gwennap
United Hills	St. Agnes
United Mines	Gwennap
Unity, Wheal	Gwennap
Unity Wood, Wheal	Kenwyn
Uny, Wheal	Redruth
Virgin, Wheal	Gwennap
Vor, Wheal	Breage
Vraws, Wheal	Sithney
Vrea, Wheal	Breage
Vyvian, Wheal	Constantine
Wallis, Wheal	Breage
Wellclose Mine	Wendron
Wellington, Wheal	Camborne
Wendron Consols	Wendron
Wendron United Mines	Wendron
Wentworth, Wheal	Redruth
West Basset	Illogan
West Bosprowal	Gwinear
West Wheal Buller	Camborne Illogan
West Carvannel	Gwennap
West Clifford	Gwennap
West Condurrow	Camborne
West Wheal Damsel	Gwennap
West Dolcoath	Camborne
West Frances	Illogan
West Wheal Grenville	Crowan
West Wheal Jane	Kea
West Wheal Jewell	Gwennap

Mine.	Parish.	Mine.	Parish.
West Lovell - -	Wendron	West Wheal Tolgus - - -	Illogan, Redruth
West Wheal Lushington -	Illogan	West Trefula -	Redruth
West Wheal Seton	Camborne	West Tresavean	Gwennap
West Wheal Towan	Illogan	West Trethellan	Gwennap
West Stray Park	Camborne	West Wheal Virgin	Gwennap
West Peevor - -	Redruth	West Wheal Vor	Breage
West Poldice -	Kenwyn, Gwennap	Widden, Wheal	Kea, Wendron

The following index gives the positions of the mines on this sheet. The Roman numerals indicate the numbers of the 6-inch and 25-inch maps issued by the Ordnance Survey. The letters indicate the quarter sheets of the 6-inch maps, while the figures represent the numbers by which the 25-inch maps are designated. Thus Dolcoath Mine LXIII., S.W. 9 means that Dolcoath is situated on the 6-inch Ordnance map LXIII. in the S.W. quarter sheet; while on the 25-inch map it is situated on sheet LXIII. in map No. 9.

BREAGE, Parish of.

Carleen Mine, LXXV., N.E. 4.
(or Carleen Wheal Vor.)
Carnmeal Mine, LXXV., N.E. 8.
(and Wheal Fortune.)
Emma, Wheal, LXXV., N.E. 8.
Fortune, Wheal, LXXV., N.E. 8.
Great Wheal Fortune, see Wheal Fortune.
Great Wheal Vor and Polladras, LXXV., N.E. 4.
Great Wheal Metal, see Wheal Metal.
Metal, Wheal, LXXV., N.E. 4.
North Wheal Vor, see Penhale Wheal Vor.
New Hendra Mine.
North Wheal Metal, part of Wheal Wallis.
Penhale Wheal Vor, LXXV., N.E. 4.
Penhale Mine, see Penhale Wheal Vor.
Pellor Wheal Metal.
Poldown, see Great Wheal Vor.
Polladras Mine, see Great Wheal Vor.
Vrea, Wheal, part of Great Wheal Vor.
Vor, Wheal, LXXV., N.E. 4.
West Wheal Vor, see Wheal Emma.
Wallis, Wheal, see Penhale Wheal Vor.

BUDOCK, Parish of.

Wheal Penrose, LXXVII., N.E. 3.

CAMBORNE, Parish of.

Bolenowe, LXIII., S.W. 14.
Camborne Consols, LXIII., S.W. 9.
Camborne Vean, LXIII., S.W. 9.
Carn Camborne, LXIII., S.W. 9.
Carnemow, see Pendarves United.
Copper Tankard, LXIII., N.W. 5.
Copper Hill, LXX., N.W. 2.
(see also in Redruth Parish.)
Crane and Bejawsa, LXIII., S.W. 9.
Crofty, Wheal, part of North Roskear.
Dolcoath Mine, LXIII., S.W. 9.
East Grenville, LXIII., S.W. 14.
East Wheal Seton, LXIII., N.W. 5.
(part of East Crofty, see in Illogan Parish.)
East Tresavean, LXIII., S.W. 14.
Frances, Wheal, see Camborne Vean.
Gerry, Wheal, LXIII., S.W. 9.
Gilly Mine, LXIII., S.W. 9.
Gine, Wheal, see Polgine.
Gons, Wheal, part of Dolcoath.
Great Condurrow, LXIII., S.W. 10.
(part of Pendarves United.)
Grenville, Wheal, LXIII., S.W. 14.
Gustavus Mine, LXIII., S.W. 9.
Harriet, Wheal, LXIII., S.W. 9.
Hatchet, Wheal, LXIII., N.W. 5.
Kellivose Mine, LXIII., S.W. 13.
King Edward Mine, part of South Condurrow.
Knight, Wheal, LXIII., N.W. 5.
Lower Bolenowe Mine, LXIII., S.W. 14.
Nelson, Wheal, LXIII., S.W. 13.
New Dolcoath, see Polgine.

New Seton, LXIII., N.W. 5.
North Dolcoath, see Dolcoath.
North Roskear, LXIII., N.W. 5.
Pendarves United (Consols), LXIII., N.W. 5.
Polgine Mine, LXIII., S.W. 14.
Roskearnoweth, part of North Roskear.
Seton, Wheal, LXIII., N.W. 5.
South Condurrow, LXIII, S.W. 14.
South Wheal Grenville, LXIII., S.W. 14.
South Roskear, LXIII., N.W. 14.
South Wheal Seton, see Gilly Mine.
South Tolcarne, LXIII., S.W. 13.
Susan, Wheal, LXIII., N.W. 5.
Tryphena, Wheal, LXIII., S.W. 13.
Wellington, Wheal, see Roskearnoweth.
West Wheal Buller, LXIII., S.W. 14.
West Condurrow, see Kellivose and South Tolcarne.
West Dolcoath, LXIII., S.W. 13.
West Wheal Seton, LXIII., N.W. 5.
West Stray Park, LXIII., S.W. 9.

CONSTANTINE, Parish of.

South Wendron Mine, LXXVI., N.E. 4.
Vyvian, Wheal, LXXVII., N.W. 1.

CROWAN, Parish of.

Abraham Consols, see Crenver and Wheal Abraham.
Carbona Mine, LXX., S.W. 9.
Clowance, Wheal, LXIX., N.E. 8.
Clowance Wood Mine, LXIX., S.E. 12.
Copper Bottom, LXIX., N.E. 8.
Courtis, Wheal, LXIX., S.E. 12.
Crenver and Wheal Abraham, LXIX., S.E. 12.
Crowan and Wendron Mine, see Parish of Wendron.
Drym Mine, see Crenver and Wheal Abraham.
East Wheal Abraham.
Gernick, LXX., N.W.
Great Drym Consols, LXIX., S.E. 12.
Hangman's Barrow, LXX., N.W.
Hender, see Copper Bottom.
Millet, Wheal, LXIX., S.E. 16.
Nancegollan, LXX., S.W. 13.
New Wheal Frances.
Nelson, Wheal, LXIII., S.W. 13.
Polcrebo Downs, LXX., S.W. 9.
Rosewarne United, LXIX., N.E. 4.
Sarah, Wheal, LXIX., S E. 12.
South Crenver.
Trevoole, LXX., N.W. 1.
West Wheal Grenville, LXX., N.W. 1.

FALMOUTH, Parish of.

Swanpool Mine, LXXI., S.E. 15.

GWENNAP, Parish of.

Ale and Cakes Mine, see United Mines.
Andrew, Wheal, LXIV., N.W. 2.
Beauchamp, Wheal, LXIII., S.E. 12.
Bell and Lannarth, LXIII., S.E. 11.
Bellvean Mine, LXIII., S.E. 12.
Bissoe Pool, LXIV., N.W. 6.
Brewer, Wheal, LXIII., S.E. 12.
Britannia, Wheal, LXIV., N.W. 5.
Carharrack, LXIII., N.E. 8.
Carqueen Mine, LXIII., N.E. 4.
Cathedral Mine, LXIII., N.E. 8.
Carvannel Mine, LXIII., S.E. 12.
Chance, Wheal, LVI., S.E. 16.
Clifford, Wheal, LXIV., N.W. 5.
Clifford Amalgamated, see United Mines and Great Consolidated Mines.
Clinton, Wheal, LXIII., N.E. 4.
Comford, Wheal, LXIII., S.E. 12.
Cupboard Hill Mines, see United Mines.
Cusvey, part of Great Consolidated Mines.
Damsel, Wheal, LXIII., N.E. 8.
East Ale and Cakes, see United Mines.
East Wheal Basset, LXIII., S.E. 11.
East Wheal Buller, see Wheal Beauchamp.
East Wheal Damsel, LXIII., N.E. 8.
East Wheal Sparnon, see Wheal Grambler.
East Wheal Virgin, part of Great Consolidated Mines.
Edgcumbe, Wheal, LXIII., S.E. 12.
Fortune, Wheal, see Great Consolidated Mines.
Friendship, see Wheal Andrew.
Girl, Wheal, part of Great Consolidated Mine.
Gorland, Wheal, LXIII., N.E. 4. (part of St. Day United.)
Grambler, Wheal, LXIII, N.E. 8. (and St. Aubyn.)
Great Consolidated Mines, LXIV., N.W. 1.
Henry, Wheal, LXIV., N.W. 1.
Hope, Wheal, see West Wheal Damsel.
Jewell, Wheal, LXIV., N.W. 1.

GWINEAR, Parish of.

ILLOGAN, Parish of.

Providence, Wheal, LXIII., S.W. 10.
Robarts, Wheal, LVI., S.W. 14.
South Wheal Basset, LXIII., S.E.11.
South Carn Brea, LXIII., N.E. 7.
South Crofty, LXIII., N.W. 6. (part of East Crofty.)
South Dolcoath, LXIII., S.W. 10.
South Wheal Ellen, see St. Agnes Parish.
South Wheal Frances, LXIII., S.W. 10.
South Tincroft, LXIII., S.W. 10.
Sparrow, Wheal, LVI., S.E. 11.
Tehidy, Wheal, LXIII., N.W. 6.
Tincroft, LXIII., N.W. 6.
Towan, Wheal, LVI., N.E. 7.
Tregajorran, LXIII., N.W. 6.
Trevenson, part of South Crofty.
West Basset Mine, LXIII., S.W. 10.
West Buller, LXIII., S.W. 14.
West Wheal Frances, LXIII., S.W. 10.
West Wheal Lushington, LVI., S.W. 10.
West Wheal Tolgus, LXIII. N.W. 2.
West Wheal Towan, see Wheal Lushington.

KEA, Parish of.

Andrew, Wheal, LXIV., N.W. 2.
Baddern, (Baddon), Wheal, LXIV., N.W. 2.
Baldhu, LXIV., N.W. 2.
Falmouth, Wheal, LVII., S.W. 14.
Falmouth and Sperries, Wheal, LVII., S.W. 14.
East Wheal Falmouth, LVII, S.W. 14.
Great Wheal Baddern, see Wheal Baddern (Baddon).
Hope, Wheal, LXIV., N.W. 2.
Jane, Wheal, LXIV., N.W. 2.
Nangiles Mine, LXIV., N.W. 2.
Sperries, Wheal, LXIV., N.W. 2.
West Wheal Jane, LXIV., N.W. 2.
Widden, Wheal, LXIV., N.W. 2.

KENWYN, Parish of.

Ann, see Wheal Seymour.
Boscawen Mine, LVI., S.E. 16. (part of Great Wheal Busy.)
Burra Burra Mine, LVII., S.W. 9.
Busy, Wheal, see Great Wheal Busy.
Chacewater Mines, see Great Wheal Busy.
Creegbraws Mine, LXIV., N.W. 1. (and Penkevil.)
Daniell, Wheal, LVII., S.W. 13.
East Wheal Chance, LVI., S.E. 16.
East Wheal Falmouth, LVII., S.W. 14.
Great Wheal Busy, LVII., S.W. 13.
Hallenbeagle Mine, see Boscawen, part of Great Wheal Busy.
Henry, Wheal, LXIV., N.W. 1.
Killifreth Mine, LVI., S.E. 16.
New Burra Burra.
New Hallenbeagle, see Boscawen.
North Wheal Busy, LVI., S.E. 12.
North Wheal Jane, LVII., S.E. 15.
Penhaldarva.
Penkevil, see Creegbraws.
Prosper, Wheal, LXIV., N.W. 1.
Scorrier Old Mine, LVI., S.E. 16.
Seymour, Wheal, LVII., S.W. 13.
South Garras.
Todpool Mine, LXIV., N.W. 1.
Tolgullow, see Unity Wood and West Poldice.
Union, see Wheal Unity Wood.
Unity Wood, Wheal, LVII., S.W. 13.
West Poldice, LXIII., N.E. 4.

MYLOR, Parish of.

Clinton, Wheal, LXXI., S.E.

PERRANARWORTHAL, Parish of.

Silver Hill
South Tresavean, LXIV.

REDRUTH, Parish of.

Barberry, Wheal, see Wheal Plenty.
Boys, Wheal, LVI., S.E. 16.
Briggan, Wheal, LVI., S.E. 16.
Buckets, Wheal, LXIII., N.E. 7.
Buller, Wheal, LXIII., S.E. 11.
Burncoose, Wheal, LXIII., N.E. 7.
Captain, Wheal, LXIII., N.E. 7.
Cardrew Consols, see Wheal Prussia.
Chance, Wheal, LVI., S.E. 16.
Clyjah and Wentworth, see Perseverance Mine.
Copper Hill, part of Wheal Buller.
Cupid, Wheal, LXIII., N.E. 4.
Derrick, Wheal, LXIII., N.E. 3.
Dopps Mine, see Pedn an Drea.
East Wheal Basset, LXIII., S.W. 11.
East Carn Brea, LXIII., N.E. 7.
East Wheal Tolgus, LXIII., N.E. 3.
Gilbert, Wheal, LXIII., N.E. 3.
Good Success Mine, see Treleigh Consols.

Great North Downs, LVII. S.E. 16
Great South Tolgus, LXIII., N.E. 7. (North Buller.)
Harmony, Wheal, LXIII., N.E. 3.
Hawk, Wheal, LVI., S.E. 16.
Lily, Wheal, LXIII., N.E. 4.
Little North Downs.
Louisa, Wheal.
Mary, Wheal, LVI., S.E. 15.
Maria, Wheal, see Treleigh Consols.
Messar, Wheal, see Great North Downs.
Montague, Wheal, LXIII., N.E. 3.
Mount Carbis, LXIII., N.E. 7.
New Treleigh, see Treleigh Consols.
North Briggan, LVI., S.E. 16.
North Buller, see Great South Tolgus.
North Wheal Buller, LXIII., N.E. 7.
North Downs, LVI., S.E. 15.
North Grambler.
North Trewan Mine, LVI., S.E. 16.
Pedn an Drea, LXIII., N.E. 7.
Peevor, Wheal, LVI., S.E. 15.
Perseverance Mine, LXIII., N.E. 7.
Pink, Wheal, LXIII., N.E. 4.
Plenty, Wheal, LVI., S.E. 15.
Prussia, Wheal, LVI., S.E. 15.
Raven, Wheal, LXIII., N.W. 2.
St. Aubyn United, LXIII., N.E. 4.
South Great Tolgus, LXIII., N.E. 7.
South Wheal Hawk, LVI., S.E. 16.
South Wheal Tolgus, LXIII., N.E. 3.
Sparnon, Wheal, LXIII., N.E. 7.
Tehidy, Wheal, LXIII., N.W. 6.
Tolans Mine, see East Wheal Tolgus.
Tolgus, Wheal, LXIII., N.E. 3.
Tolgus United Mine, LXIII., N.E 3.
Trefula Mine, see Wheal Lily.
Trelawney, Wheal, LXIII., N.E. 8.
Treleigh Consols, LVI., S.E. 15.
Treleighwood Mine, LXIII., N.E. 3.
Tresavean Mine, LXIII., S.E. 11.
Trewirgie Downs, see Wheal Buller.
Union, Wheal, LXIII., N.E. 3.
Uny, Wheal, LXIII., N.E. 7.
Wentworth, see Perseverance.
West Peevor, LVI., S.E. 15.
West Wheal Tolgus, LXIII., N.W. 6.
West Trefula, LXIII., N.E. 3.

ST. AGNES, Parish of.

Banns, Wheal, LVI., N.E. 7.
Charles, Wheal, LVI., N.E. 7.
Cornwall, LVII., N.W. 5.
Concord, see North Treskerby.
East Wheal Ellen. (?)
East Downs Mine, LVI., S.E. 16.
East Wheal Music, LVI., N.E. 8.
East Treskerby. (?)
East Wheal Towan, LVI., N.E. 7.
Ellen, Wheal, LVI., S.E. 11.
Fancy, Wheal, LVI., N.E. 7.
Music, Wheal, now Wheal Ellen.
North Wheal Basset, LVI., S.E. 11.
North Hallenbeagle, LVI., N.E. 8.
North Treskerby, LVI., S.E. 16.
Rose, Wheal, LVI., S.E. 16.
Rose Ann Mine, LVI., N.E. 7.
Scorrier Consols, LVI., S.E. 12.
South Wheal Ellen, LVI., S.E. 11.
South Wheal Towan, LVI., N.E. 7.
Tallack, Wheal, LVI., N.E. 7.
Towan Consols, LVI., N.E. 7.
Towan, Wheal, LVI., N.E. 7.
Trenithick Mine, LVI., N.E. 8.
Tywarnhayle Mine, LVI., N.E. 7.
United Hills, LVI., N.E. 7.

ST. GLUVIAS, Parish of.

Roskrow United, LXIV., S.W. E.

SITHNEY, Parish of.

Bramble, Wheal, LXX., S.W. 13.
Christopher, LXX., S.W. 13.
East Wheal Vor. (?)
East Wheal Fortune, see Sithney Wheal Vor.
Fursden, Wheal, LXX., S.W. 14.
Harriet, Wheal, LXXVI., N.W. 2.
Mount, Wheal, LXXVI., N.W. 2.
New Vor and Metal United.
North Metal Mine, LXXV., N.E. 4.
North Prospidnick, LXX., S.W. 13.
Peverill, Wheal, see Wheal Fursden.
Polcrebo Downs, LXX., S.W. 9.
Prospidnick Mine, LXX., S.W. 13.
Sithney, Wheal, LXXVI., N.W. 5.
Sithney Carnmeal Mine, LXXVI., N.W. 1.
Sithney, Wheal Metal, LXXV., N.E. 4.
Sithney Wheal Vor. (?)
Trannack, Wheal, LXXVI., N.W. 2.
Trevarno Mine, LXXVI., N.W. 1.
Vraws, Wheal, see North Prospidnick Mine.

STITHIANS, Parish of.

Trelusback Mine, LXIII., S.E. 16.

WENDRON, Parish of.

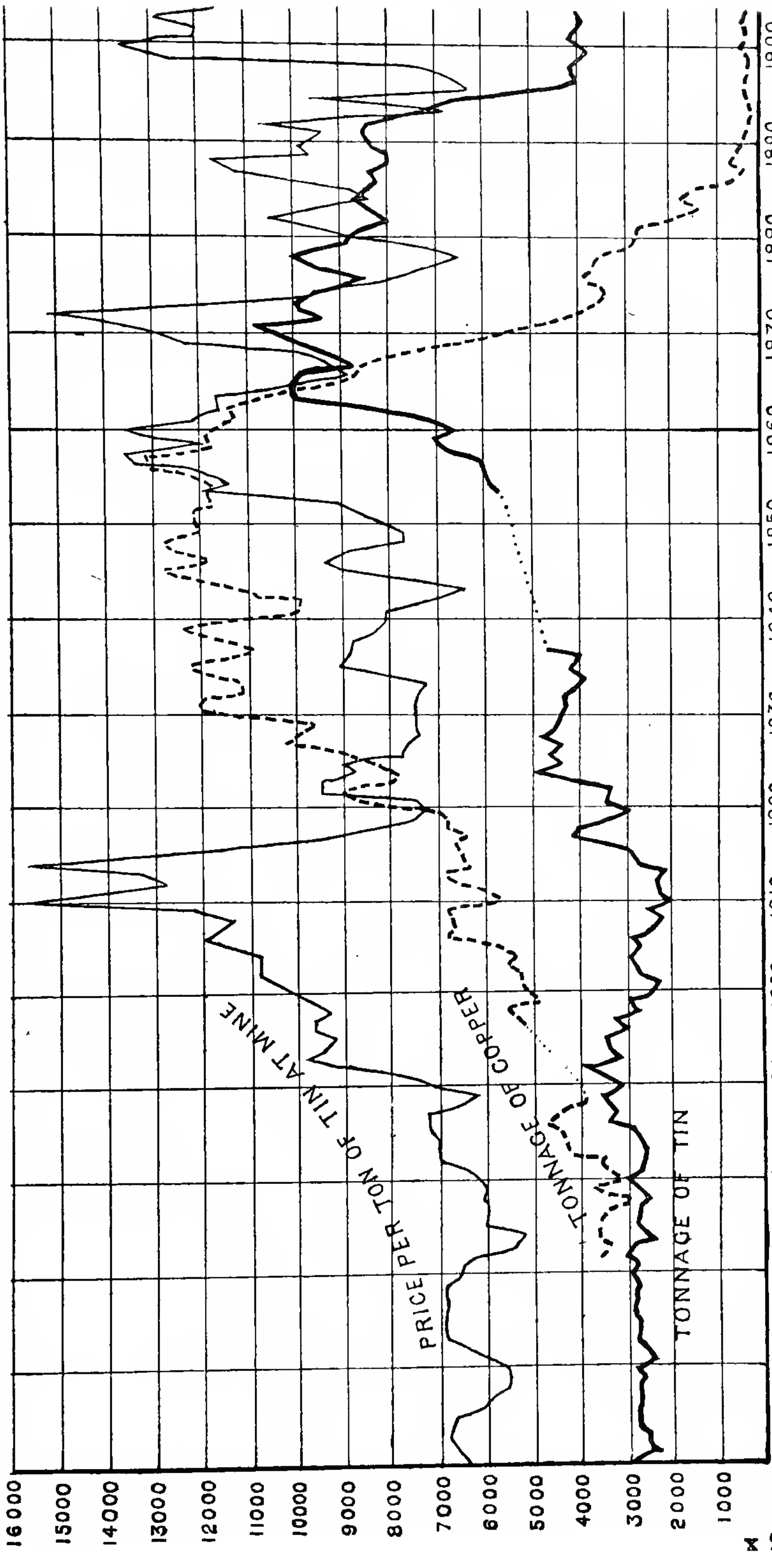
Ann, Wheal, LXXVI., N.W. 2. (or Trumpet United.)
Bal Ding, LXX., S.E. 12.
Basset and Grylls, Wheal LXX., S.E. 11.
Buller and Basset United Mine, LXIII., S.E. 15.
Balmynheer Mine, LXX., N.E. 7.
Bodilly Consols, LXX., S.W. 14.
Calvadnack Mine, LXX., N.E. 7.
Cudy, Wheal, LXX., S.E. 15.
Crowan and Wendron Mine, formerly Releath Mine.
Combellack Mine, LXXVI., N.E. 3.
Dream, Wheal, LXXVI., N.W. 2.
Duchy, Wheal, see Old Wheal Lovell.
East Trumpet Mine, LXXVI., N.W. 2.
East Wheal Lovell, LXX., S.E. 15.
Enys, Wheal, LXX., S.E. 11.
Foster, Wheal, LXX., S.E. 11.
Garlidna, LXX., S.E. 11.
Great Wheal Lovell, LXXVI., N.E. 3.
Great East Lovell.
Lovell, Wheal, LXXVI., N.E. 3.
Medlyn Moor Mine, LXX., S.E. 11.
Mengearn, LXXVI., N.E. 3.
New Wheal Lovell, LXXVI., N.E. 3.
New Trevenen.
New Trumpet Consols, LXXVI., N.E. 3.
New Wendron.
North Lovell Mine, LXX., S.E. 11.
Old Wheal Lovell.
Old Trevenen Mine, LXXVI. N.W. 2.
Polengrean, see Garlidna.
Polhigey Mine, LXX., N.E. 7.
Porkellis United, see Basset and Grylls.
Porkellis Moor, LXX., S.E. 15.
Releath Mine or Crowan and Wendron Mine, LXX., S.W. 10.
Retanna Hill Mine, LXX., S.E. 12.
Roselidden Mine, LXXVI., N.W. 2.
South Lovell.
South Wendron Mine, LXXVI. N.E. 4.
Tregonebris see East Wheal Lovell.
Tremenheere Mine, LXXVI., N.W. 6.
Trenithick Wood Mine, LXXVI., N.W. 6.
Trevenen Bal, LXXVI., N.W. 2.
Trevenen Mine, LXXVI., N.E. 3.
Trenear Mine, LXX., S.E. 15.
Treworlis Mine, LXXVI., N.W. 6.
Trumpet Consols Mine, LXXVI., N.W. 2.
Wellclose Mine, LXXVI., N.W. 2.
Wendron Consols, LXX., S.E. 15.
Wendron United Mines, LXX., N.E. 7.
Widden, Wheal, LXXVI., N.W. 2.
West Lovell.

TOTAL YIELD OF TIN AND COPPER IN CORNWALL (Fig. 65.)

The following statistical table has been compiled from numerous publications containing details of the annual output of ore, yield of metal, amount realised by sales, produce, standard price, and price of metal on market, but it should be remarked that the figures given by some of the authorities who have made independent estimates for certain years do not agree. This is probably owing to the same general difficulties as were experienced in estimating the total yield of the individual mines, namely, that the private sales were not formerly divulged in the way that the amounts sold by public ticketing were. The table, which up to 1882 is largely from Hunt's "British Mining," may be regarded as fairly reliable, and since 1882 as quite trustworthy. In its preparation the following are the principal works that have been consulted:—

Pryce.—"*Mineralogia Cornubiensis*," 1778. Annual output of copper ore from 1726 to 1775. Prior to 1760 the amounts are only given in round figures (p. 14).

FIG. 65.—*Diagram showing the yield of metallic tin and copper in Cornwall, estimated from public sales of ore.*



The figures on the vertical scale refer to the tonnage, but when divided by 100 they refer to the price of metallic tin per ton in pounds sterling at the mine as indicated by the thin continuous line.

X 2

Gilbert, C. S.—"History of Cornwall," vol. ii., 1817, p. 707. Annual output of tin (in blocks* and tons) from 1750 to 1816.

Trans. Roy. Geol. Soc. Corn., vol. ii., 1822, vol. iii., 1828, vol. iv., 1832. Yield of copper ore and copper, &c., from 1771 to 1832.

Grylls, H.—"A Synopsis of Mining from 1729 to 1833." Copper ore, copper, &c., from 1729 to 1832. Blocks of tin from 1750 to 1832.

Lemon, Sir Charles.—*Journ. Stat. Soc.*, vol. i., 1838, p. 70.

Courtney, J. S.—"A Treatise on the Statistics of Cornwall," *Rep. Roy. Corn. Poly. Soc.*, 1838, p. 81. Tonnage of tin from 1750.

Carne, J.—"Statistics of the Tin Mines of Cornwall and of the Consumption of Tin," *Journ. Stat. Soc.*, vol. ii., 1839. Tonnage from 1750 to 1837.

De la Beche, H. T.—"Geological Report of Cornwall, Devon, and West Somerset," 1839, p. 606. Copper ore and copper, &c., from 1771 to 1838.

"Mineral Statistics," *Mem. Geol. Surv.*, 1848 to 1881. Copper ore, copper, black tin, metallic tin, standard and market prices, &c.

Grylls, H.—"Annual Mining Sheet," No. 21, 1852. Copper ore, &c., from 1833 to 1852.

Hunt, R.—"British Mining," 1884. Copper ore, copper, black tin, metallic tin, standard and market prices, &c., from 1726 to 1882.

"Mines and Quarries, General Report and Statistics" (Home Office), part iii., Output. All products and prices from 1882 to 1905.

In the statistical table the price of copper has been given in two ways: (1) the price which the miner received for each ton of copper in the ore sold, and (2) the price of copper on the London market. In a third column the standard for copper is also given, and this is the sum which governed the money transactions between the smelter and the miner, and was not a sum actually paid. The term has been explained by Percy, Lemon, Rickard, Phillips and Darlington, Salmon, Hunt, and others.

In the early days of copper mining the smelters generally made contracts with the miners for definite periods and undertook to buy the ore at a certain rate, which was determined by a standard price previously agreed on by the miner and smelter, and this was usually the selling price of tough cake copper. The standard having been settled, the sum which the miner received for the copper in the ore was at this rate; but he paid back to the smelter a certain sum known as the "returning charges," generally £2 15s. per ton of ore. These "returning charges" were generally in excess of the actual cost of smelting, so that this was one source of profit to the smelter. The miner further gave him an extra cwt. in the ton to cover losses in carriage, and he also made allowance for moisture. Another source of profit to the smelter arose from the fact that the percentage of copper shown by the assayer's results was generally lower than the percentage procurable in smelting.† As there was a certain "returning charge" due to the smelter on every ton of ore, it paid him better to buy low-grade ores than rich ones, as the proportional cost of extraction per ton of metallic copper to the total amount of the returning charges was less. It was to the smelter's advantage to keep the standard as low as possible and to the miner's interest to raise it.

* A block weighs from 360 to 380 lbs. There are, roughly, about 6½ blocks in a ton. The weight of a block has, however, varied from time to time. In 1305 it was 126 lbs.; in 1577, 308 lbs.; in 1587, 324 lbs.; in 1597, 335 lbs.; in 1607 it was 346 lbs, Sir John MacLean, *Journ. Roy. Inst. Corn.*, 1874, p. 187.

† "The amount of copper obtainable by smelting British ores is about $\frac{1}{25}$ or 4 per cent. more than the amount calculated from the dry assay. Thus, in the case of an ore containing 5 per cent. of metal by dry assay, the actual yield has been taken as $5\frac{1}{5}$ per cent."—"General Statistics," part iii., Output, p. 200.

As competition increased and the market price of copper became fixed by auction at public ticketings, the importance of the "standard" was diminished, but for the sake of comparison it was calculated, after the sales, from the market price of copper and the produce of the ore.

In early days, therefore, the standard was an amount agreed upon by the miner and smelter, and determined the amount the miner was to receive for the ore. In later times it ceased to have any value beyond affording a means of making comparison, and instead of being a sum agreed on, it was an amount calculated from the selling price of the copper.

Method of calculating the price of Copper in early days.	Method of calculating the standard in later times.*
Tough cake copper sold at £120 per ton. (Has nothing to do with the estimation.) The standard agreed on = 118. Suppose 140 tons of ore containiug 8 per cent. of copper on sale. Returning charge = 140 × £2 15 = £385. Amount of copper in ore, viz., 8 per cent. = 11·2 tons. Value of copper in ore, according to standard = 11·2 × £118 = £1,321·6 ∴ Amount received by miner = £1,321·6 − £385 = £936·6 = £67 per ton.	140 tons of ore containing 8 per cent. copper, sold at public ticketing, for £936·6 The standard is calculated as follows:— The returning charge = 140 × £2 15s. = £385. ∴ £936·6 + £385 = £1,321·6 ∴ $\frac{£1,321·6.}{11·2}$ = £118 per ton (standard).

The smelter, in estimating the value of the ore before making his offer to the miner, generally consults a table prepared from actual practice, showing the cost of working the ore, which guides him in his calculation. The following is an abbreviated example of a page in the smelter's note book:—

				£	s.	d.	
Cost of working	5 per cent.	copper ore is		16	19	10	per ton of copper.
,, ,,	10 ,,	,, ,,		11	3	6	,, ,,
,, ,,	15 ,,	,, ,,		9	4	10	,, ,,
,, ,,	20 ,,		if calcined, is	8	9	2	,, ,,
,, ,,	20 ,,		if not calcined, is	6	19	2	,, ,,
,, ,,	30 ,,		if calcined, is	6	9	2	,, ,,
,, ,,	30 ,,		if not calcined, is	5	9	2	,, ,,
,, ,,	50 ,,		if calcined, is	4	15	8	,, ,,
,, ,,	50 ,,		if not calcined, is	4	3	8	,, ,,
,, ,,	70 ,,		(precipitate)	3	15	5	,, ,,

With regard to tin, the "standard is the amount paid by the smelter per cwt. of metal contained in the ore, as calculated from the results of an assay by the dry method, after deduction of 1¼ from the produce per 20 (6¼ per cent.) for returning charges. By an old trade custom there is also a deduction on the weight of the parcel of tin ore of 3 lbs. per cwt. It is customary to reckon the price to the nearest eighth of a pound sterling above or below the calculated price."†

* The standard price should not be confused with the term standard copper, which, according to Brown and Turnbull, "A Century of Copper," 1900, contains 96 per cent. of copper. Tough copper containing 99½ per cent. See also Part III., "General Statistics."

† "General Statistics," part iii., Output.

Date.	Black Tin.	Metallic Tin.	Price per Ton Metallic Tin.			Copper Ore.	Metallic Copper.	Standard.			Value of Copper at Mine, per Ton.		
	Tons.	Tons.	£	s.	d.	Tons. Cornwall.	Tons.	£	s.	d.	£	s.	d.
1726	...	...		...		5,000	...		...			...	
1727	...	...		...		6,700	...		...			...	
1728	...	...		...		6,800	...		...			...	
1729	...	...		...		6,870	...		...			...	
1730	...	...		...		6,900	...		...			...	
1731	...	...		...		7,000	...		...			...	
1732	...	...		...		7,290	...		...			...	
1733	...	...		...		7,000	...		...			...	
1734	...	...		...		6,000	...		...			...	
1735	...	...		...		5,240	...		...			...	
1736	...	...		...		8,000	...		...			...	
1737	...	...		...		9,000	...		...			...	
1738	...	...		...		10,000	...		...			...	
1739	...	...		...		11,000	...		...			...	
1740	...	...		...		5,000	...		...			...	
1741	...	...		...		5,500	...		...			...	
1742	...	...		...		6,050	...		...			...	
1743	...	...		...		7,040	...		...			...	
1744	...	...		...		7,230	...		...			...	
1745	...	...		...		6,700	...		...			...	
1746	...	...		...		7,000	...		...			...	
1747	...	...		...		4,900	...		...			...	
1748	...	...		...		6,000	...		...			...	
1749	...	...		...		7,200	...		...			...	
1750	...	2,876	64	17	6	9,400	...		...			...	
1751	...	2,273	65	2	6	11,000	...		...			...	
1752	...	2,550	67	2	6	12,050	...		...			...	
1753	...	2,516	68	0	0	13,000	...		...			...	
1754	...	2,724	67	17	6	14,000	...		...			...	
1755	...	2,757	67	0	0	14,240	...		...			...	
1756	...	2,774	62	12	6	16,000	...		...			...	
1757	...	2,752	59	5	0	17,000	...		...			...	
1758	...	2,720	56	5	0	15,000	...		...			...	
1759	...	2,637	56	0	0	16,700	...		...			...	
1760	...	2,717	56	0	0	15,780	...		...			...	
1761	...	2,395	59	17	6	17,004	...		...			...	
1762	...	2,584	64	15	0	16,054	...		...			...	
1763	...	2,736	68	17	6	17,898	...		...			...	
1764	...	2,618	69	0	0	21,489	...		...			...	
1765	...	2,757	69	0	0	16,774	...		...			...	
1766	...	3,055	69	0	0	21,251	...		...			...	
1767	...	2,850	69	0	0	18,502	...		...			...	
1768	...	2,667	69	0	0	23,671	...		...			...	
1769	...	2,898	69	0	0	26,655	...		...			...	
1770	...	2,977	66	10	0	30,776	...		...			...	
1771	...	2,823	65	0	0	27,896	3,347	81	0	0	(*Estimated*)		
1772	...	3,159	63	5	0	27,965	3,556	81	0	0	53	0	0
1773	...	2,852	54	0	0	27,663	3,320	70	0	0	45	0	0
1774	...	2,458	52	10	0	30,254	3,630	68	0	0	44	0	0
1775	...	2,619	60	0	0	29,966	3,596	78	0	0	53	0	0
1776	...	2,652	59	15	0	29,433	3,532	79	0	0	54	0	0
1777	...	2,770	59	10	0	28,216	3,386	77	0	0	52	0	0
1778	...	2,515	60	10	0	24,706	2,965	72	0	0	49	0	0
1779	...	2,678	60	0	0	31,115	3,734	73	0	0	48	0	0
1780	...	2,926	61	5	0	24,433	2,932	83	0	0	58	0	0
1781	...	2,610	64	5	0	28,749	3,450	77	0	0	52	0	0
1782	...	2,546	70	0	0	28,122	3,375	70	0	0	45	0	0

Date.	Black Tin.	Metallic Tin.	Price per Ton Metallic Tin.			Copper Ore.	Metallic Copper.	Standard.			Value of Copper at Mine, per Ton.		
	Tons.	Tons.	£	s.	d.	Tons. Cornwall.	Tons.	£.	s.	d.	£	s.	d.
1783	...	2,570	70	0	0	35,799	4,296	76	0	0	51	0	0
1784	...	2,685	70	10	0	36,601	4,392	72	0	0	47	0	0
1785	...	2,885	72	0	0	36,959	4,434	71	0	0	46	0	0
1786	...	3,399	72	0	0	39,895	4,787	75	0	0	50	0	0
1787	...	3 204	72	0	0	38,047	4,500	67	0	0	43	0	0
1788	...	3,352	66	10	0	31,541	3,800	57	0	0	40	0	0
1789	...	3,405	62	10	0	33,281	3,900	63	0	0	47	0	0
1790	...	3,193	72	10	0	34,700	4,100						
1791	...	3,470	79	0	0	36,500	4,250	*Estimated.*					
1792	...	3,809	92	10	0	38,300	4,450						
1793	...	3,202	98	0	0	40,000	4,650						
1794	...	3,351	95	10	0	42,816	4,920	88	0	0	67	0	0
1795	...	3,440	93	0	0	43,589	5,070	87	0	0	64	0	0
1796	...	3,061	96	10	0	43,313	5,120	93	0	0	70	0	0
1797	...	3,240	97	0	0	47,909	5,201	96	0	0	72	0	0
1798	...	2,820	94	0	0	51,358	5,600	...			...		
1799	...	2,862	97	0	0	51,273	4,923	121	0	0	95	0	0
1800	...	2,522	101	0	0	55 981	5,187	133	3	0	106	0	0
1801	...	2,328	105	0	0	56,611	5,267	117	5	0	90	0	0
1802	...	2,627	108	10	0	53,937	5,228	110	18	0	84	0	0
1803	...	2,914	109	0	0	60,566	5,615	122	0	0	95	0	0
1804	...	2,993	109	0	0	64,637	5,375	136	5	0	106	0	0
1805	...	2,742	112	10	0	78,452	6,234	169	16	0	138	0	0
1806	...	2,855	120	10	0	79,269	6,863	138	5	0	106	0	0
1807	...	2,426	117	10	0	71 694	6,716	120	0	0	91	0	0
1808	...	2,330	114	0	0	67,867	6,795	100	17	0	74	0	0
1809	...	2,508	122	0	0	76,245	6,821	143	12	0	113	0	0
1810	...	2,006	157	0	0	66,048	5,682	132	5	0	100	0	0
1811	...	2,384	141	10	0	66,786	6,141	120	10	0	90	0	0
1812	...	2,373	128	0	0	71,547	6,720	111	1	0	82	0	0
1813	...	2,324	134	0	0	74,047	6,918	115	7	0	86	0	0
1814	...	2,611	156	10	0	74,322	6,369	130	12	0	99	0	0
1815	...	2,941	140	10	0	78,483	6,525	117	16	0	85	0	0
1816	...	3,348	114	10	0	77,334	6,697	98	13	0	68	0	0
1817	...	4,120	93	10	0	76,701	6,498	108	10	0	76	0	0
		Cornwall and Devon.											
1818	...	4,066	84	15	0	86,174	6,849	134	15	0	104	0	0
1819	...	3,315	75	5	0	88,736	6,804	127	10	0	92	0	0
1820	...	2,990	73	5	0	91,473	7,508	113	15	0	80	0	0
1821	...	3,373	75	13	4	98,426	8,515	103	0	0	71	0	0
1822	...	3,278	95	10	0	104,523	9,140	104	0	0	74	0	0
1823	...	4 213	94	15	0	95,750	7,928	109	18	0	78	0	0
1824	...	5,005	88	0	0	99,700	7,824	110	0	0	99	0	0
1825	...	4,358	91	6	8	107,454	8,226	114	0	0	97	0	0
1826	...	4,603	77	0	0	117,308	9,026	123	3	0	72	0	0
1827	...	5,555	76	0	0	126,710	10,311	106	1	0	75	0	0
1828	...	4,931	73	5	0	130,366	9,921	112	7	0	72	0	0
1829	...	4,434	74	0	0	124,502	9,656	109	14	0	73	0	0
1830	...	4,444	73	15	0	133,904	10,748	106	5	0	69	0	0
1831	...	4,300	73	10	0	144,402	12,044	100	0	0	68	0	0
1832	...	4,323	72	15	0	137,357	11,947	100	0	0	72	0	0
1833	...	4,065	72	15	0	138,300	11,191	111	0	0	74	0	0
1834	...	3,989	78	0	0	143 296	11,225	114	0	0	79	0	0
1835	...	4 228	91	0	0	150,617	12,270	106	11	0	73	0	0
1836	...	4,054	109	10	0	140,981	11 647	115	12	0	82	0	0

Date.	Black Tin.	Metallic Tin.	Price per Ton of Black Tin at Mine.	Price of Metallic Tin per Ton.	Copper Ore.	Copper.	Standard.	Value of Copper at Mine per Ton.	Average Price of Best Selected Copper in London.
	Tons.	Tons.	£ s. d.	£ s. d.	Tons.	Tons.	£ s. d.	£ s. d.	£ s. d.
1837 -	—	4,796	—	88 0 0	140,753	10,823	119 0 0	83 0 0	—
1838 -	—	2,652	—	88 0 0	145,688	11,527	109 0 0	75 0 0	—
1839 -	—	—	—	83 0 0	159,551	12,450	110 0 0	75 0 0	—
1840 -	—	—	—	81 0 0	147,266	11,037	108 10 0	72 0 0	—
1841 -	—	—	—	81 0 0	147,846	9,987	119 0 0	82 0 0	—
1842 -	—	—	—	72 0 0	154,180	9,896	120 0 0	84 0 0	—
1843 -	—	—	—	64 0 0	153,668	10,926	110 0 0	73 0 0	—
1844 -	—	—	—	74 0 0	152,667	11,246	109 0 0	73 0 0	—
1845 -	—	—	—	91 0 0	162,557	12,883	103 0 0	65 0 0	—
1846 -	—	—	—	94 0 0	150,431	11,850	106 0 0	75 0 0	—
1847 -	—	—	—	89 0 0	155,985	12,754	103 12 0	65 0 0	—
1848 -	10,176	—	—	77 0 0	155,616	12,869	97 7 0	64 0 0	—
1849 -	10,719	—	—	78 0 0	144,983	12,052	92 11 0	60 0 0	—
1850 -	10,383	—	—	81 0 0	155,025	12,253	103 19 0	66 0 0	—
1851 -	9,455	—	—	87 0 0	154,299	12,199	101 0 0	68 0 0	—
1852 -	9,672	—	—	92 0 0	165,593	11,776	106 12 0	70 0 0	—
1853 -	8,866	5,763	68 0 0	115 0 0	180,095	11,839	136 16 0	97 0 0	—
1854 -	8,747	5,947	64 0 0	114 0 0	180,687	11,779	140 2 0	99 0 0	—
1855 -	8,947	6,000	68 0 0	120 0 0	188,969	12,242	141 10 0	100 0 0	129 0 0
1856 -	9,350	6,177	71 0 0	133 0 0	209,305	13,274	140 0 0	92 0 0	123 0 0
1857 -	9,783	6,582	76 0 0	136 0 0	198,697	13,088	139 6 0	99 0 0	124 0 0
1858 -	10,618	6,920	63 4 0	119 2 2	183,292	11,764	135 1 0	89 0 0	108 0 0
1859 -	10,670	7,100	74 15 0	130 18 3	183,944	11,888	133 6 0	92 0 0	112 7 0
1860 -	10,462	6,695	71 11 0	136 3 1	180,448	11,769	133 8 0	90 0 0	109 13 0

Estimated from Quarterly Prices.

Date.	Black Tin.	Metallic Tin.	Price per Ton of Black Tin at Mine.	Price of Metallic Tin per Ton.	Copper Ore.	Copper.	Standard.	Value of Copper at Mine per Ton.	Average Price of Best Selected Copper in London.
	Tons.	Tons.	£ s. d.	£ s. d.	Tons.	Tons.	£ s. d.	£ s. d.	£ s. d.
1861 -	11,640	7,450	62 6 8	122 5 0	180,778	11,486	130 15 0	87 0 0	102 12 0
1862 -	14,127	8,476	59 14 0	116 0 0	183,313	11,566	123 16 0	80 0 0	100 12 0
1863 -	15,157	10,006	63 12 0	117 0 0	169,971	10,896	119 5 0	73 0 0	98 17 0
1864 -	15,211	10,108	60 17 0	107 1 0	165,601	10,273	127 19 0	83 0 0	101 8 0
1865 -	15,686	10,039	55 6 0	96 15 0	159,409	9,750	122 12 0	78 0 0	94 7 0
1866 -	15,080	9,990	48 10 0	88 12 0	138,141	8,799	109 7 0	66 0 0	91 14 0
1867 -	13,649	8,700	50 18 0	91 17 0	119,766	8,027	110 9 0	68 0 0	82 8 0
1868 -	13,953	9,300	55 4 0	98 0 0	117,262	7,667	107 10 0	64 0 0	78 15 0
1869 -	14,725	9,760	69 16 0	123 2 0	94,606	6,544	101 6 0	60 0 0	77 10 0
1870 -	15,234	10,200	75 3 0	127 8 6	81,278	5,606	98 1 0	60 0 0	72 13 0
1871 -	16,272	10,900	78 12 6	137 10 0	71,118	4,682	102 10 0	60 0 0	77 10 0
1872 -	14,266	9,560	87 7 0	152 15 0	65,386	4,129	119 18 0	77 0 0	104 5 0
1873 -	14,885	9,972	78 1 0	133 7 0	55,095	3,782	102 11 0	63 0 0	95 18 0
1874 -	14,039	9,942	56 3 0	108 8 0	49,175	3,542	103 0 0	65 0 0	89 12 0
1875 -	13,995	9,614	52 11 0	90 2 0	51,122	3,521	113 7 0	75 0 0	90 0 0
1876 -	13,688	8,500	43 18 0	79 10 2	57,985	3,841	107 9 0	67 0 0	83 0 0
1877 -	14,142	9,500	40 10 0	73 3 6	53,785	3,714	97 6 0	58 0 0	75 16 0
1878 -	15,045	10,106	35 5 0	65 12 3	47,591	3,390	88 4 0	50 0 0	68 11 0
1879 -	14,665	9,532	40 0 0	72 6 0	42,094	2,889	89 5 0	49 0 0	64 5 0
1880 -	13,737	8,918	49 0 0	91 5 0	40,311	2,754	95 0 0	55 0 0	69 5 0
1881 -	12,900	8,600	54 0 0	97 9 3	40,584	2,681	94 8 0	53 0 0	68 0 0
	Output from	Mines in	Cornwall only.	English block in Lond'n m'rkt					
1882 -	12,470	8,077	57 7 6	106 14 0	25,641	1,865	—	61 0 0	73 0 0

Date.	Black Tin.	Metallic Tin.	Price per Ton of Black Tin at Mine.	Price of Metallic Tin per Ton.	Copper Ore.	Copper.	Standard.	Value of Copper at Mine per Ton.	Average Price of Best Selected Copper in London.
	Tons.	Tons.	£ s. d.	£ s. d.	Tons.	Tons.	£ s. d.	£ s. d.	£ s. d.
1883 -	12,890	8,419	50 16 0	97 1 6	23,250	1,362	—	64 0 0	69 3 3
1884 -	13,622	8,709	44 5 0	84 11 7	21,539	1,792	—	36 0 0	60 9 6
1885 -	12,934	8,470	46 1 6	89 7 2	19,734	1,578	—	32 0 0	48 16 8
1886 -	12,780	8,378	54 16 6	101 8 6	7,541	680	—	30 0 0	44 10 6
1887 -	12,740	8,406	61 18 9	112 19 6	3,415	358	—	28 0 0	48 4 0
1888 -	12,451	8,080	62 7 0	117 5 5	6,838	688	—	54 0 0	79 11 4
1889 -	12,411	8,067	52 14 8	96 10 9	4,959	496	—	31 0 0	55 3 10
1890 -	12,944	8,414	52 10 0	97 13 3	5,271	375	—	41 0 0	61 11 10
1891 -	13,029	8,470	50 15 0	94 4 1	4,290	305	—	37 0 0	56 11 2
1892 -	12,890	8,418	51 3 6	96 10 5	2,813	200	—	32 0 0	49 18 10
1893 -	12,343	8,023	46 10 9	88 18 2	2,673	190	—	35 0 0	48 3 11
1894 -	11,507	7,480	37 15 3	72 11 10	3,362	239	—	45 0 0	43 12 8
1895 -	10,582	6,627	35 17 0	97 4 1	5,504	391	—	46 0 0	47 1 4
1896 -	7,657	4,833	33 18 4	63 12 0	5,616	399	—	45 0 0	50 13 8
1897 -	6,214	4,039	35 14 1	65 8 7	4,140	294	—	43 0 0	52 5 8
1898 -	6.586	4,281	39 1 4	74 8 1	5,293	374	—	42 0 0	55 9 8
1899 -	5,659	3,678	68 18 3	126 12 1	5,172	367	—	39 0 0	78 2 7
1900 -	5,991	3,894	75 19 9	137 14 7	5,926	462	—	52 0 0	78 8 6
1901 -	6,533	4,246	62 18 6	121 0 1	4,251	332	—	60 0 0	73 7 2
1902 -	6,690	4,014	67 19 5	121 4 1	4,547	318	—	39 0 0	56 13 8
1903 -	6,471	3,882	72 2 8	129 8 1	5,351	401	—	41 0 0	63 0 10
1904 -	5,991	3,778.	71 2 10	128 8 1	4,433	347	—	—	63 0 3
1905 -	7,174	4,450	79 14 8	143 12 3	4,651	358	—	—	74 11 5

APPENDIX.

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Plate II.

Trefusis, Falmouth Harbour.

The Pliocene platform is seen along the sky-line. The Pleistocene platform capped by Raised Beach and Head makes the feature skirting the shore of the estuary.

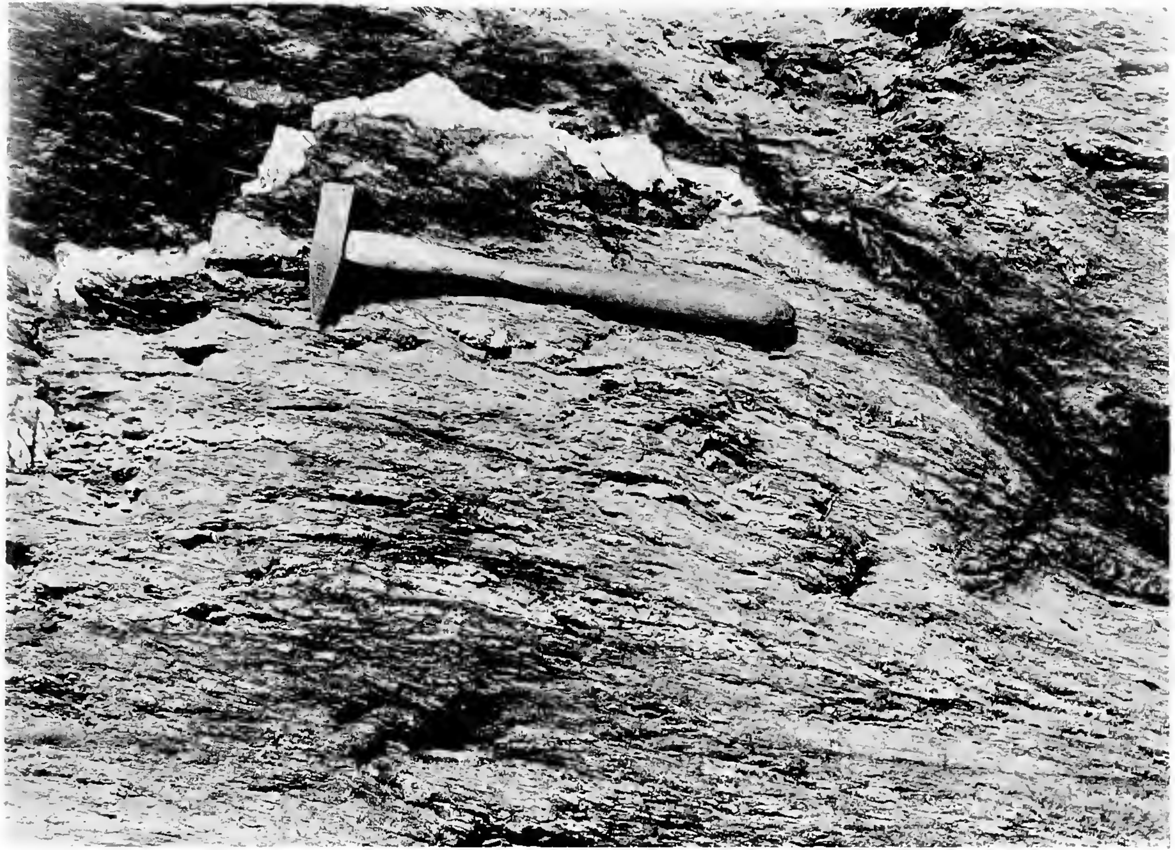
PLATE III.

THE CAMBORNE MINING DISTRICT, WITH CARN BREA IN THE DISTANCE.

SUNNY COVE, FALMOUTH
Portscatho Slate Series showing contortion and quartz veining.

SUNNY COVE, FALMOUTH.

Portscatho Series showing bedding, cleavage, and jointing.
In the sandy bands the cleavage is seen oblique to the bedding.

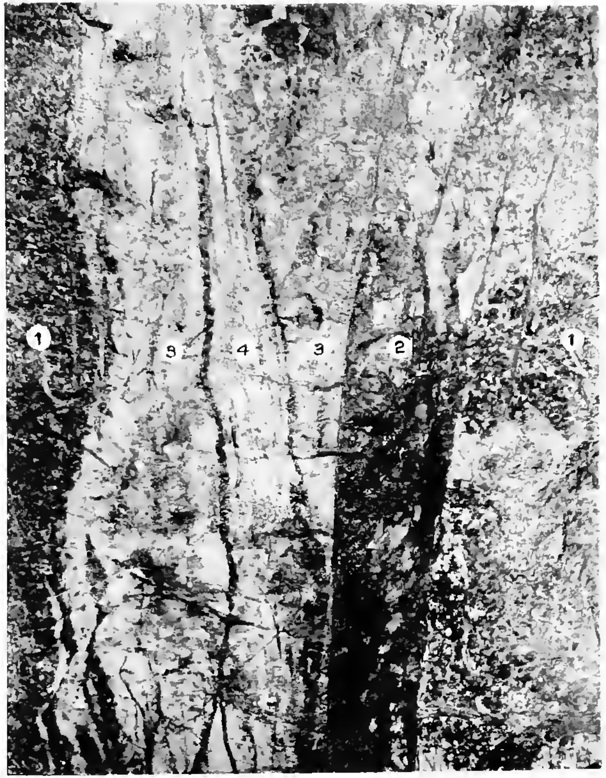


RESTRONGUET POINT. CARRICK ROADS.

Mylor Series showing brecciation resulting in the production of pseudo-conglomerate
The large quartz vein exhibits the initial stages of the process.

CARN BREA.
Granite tor with stratiform weathering.

SUNNY COVE, FALMOUTH.
Pleistocene platforms slightly above the modern coastal shelf. They are carved out of the Portscatho series and capped on the landward side by Head. A relic of the Raised Beach is seen in the foreground at the base of the Head.



LODE STRUCTURES.

A.

Middle Lode. South Crofty Mine.

1 Capel (Tourmaline rock and greisen).
2. Vein of Tourmaline peach.
3. Quartz vein.
4. Quartz vein between veins of peach.

B.

Caunter Lode. East Pool Mine.

1. Quartz, fluorspar, and a little chlorite.
2. Strings of chlorite and cassiterite.
3. Quartz and chalybite.
4. Strings of chlorite. Cavities lined with quartz and filled with chalybite.

A.

B.

C.

Specimens of Veinstone.

The left hand specimen is from the 300 fathom level in Wheal Grenville. It is a tough brecciated tourmaline peach cemented by quartz. The middle specimen is from East Pool and consists of quartz, wolfram (shown black in the figure), and mispickel. The right hand specimen is from the 475-fathom level in Dolcoath. It is a tough tourmaline peach finely brecciated and cemented by cassiterite and quartz, &c.

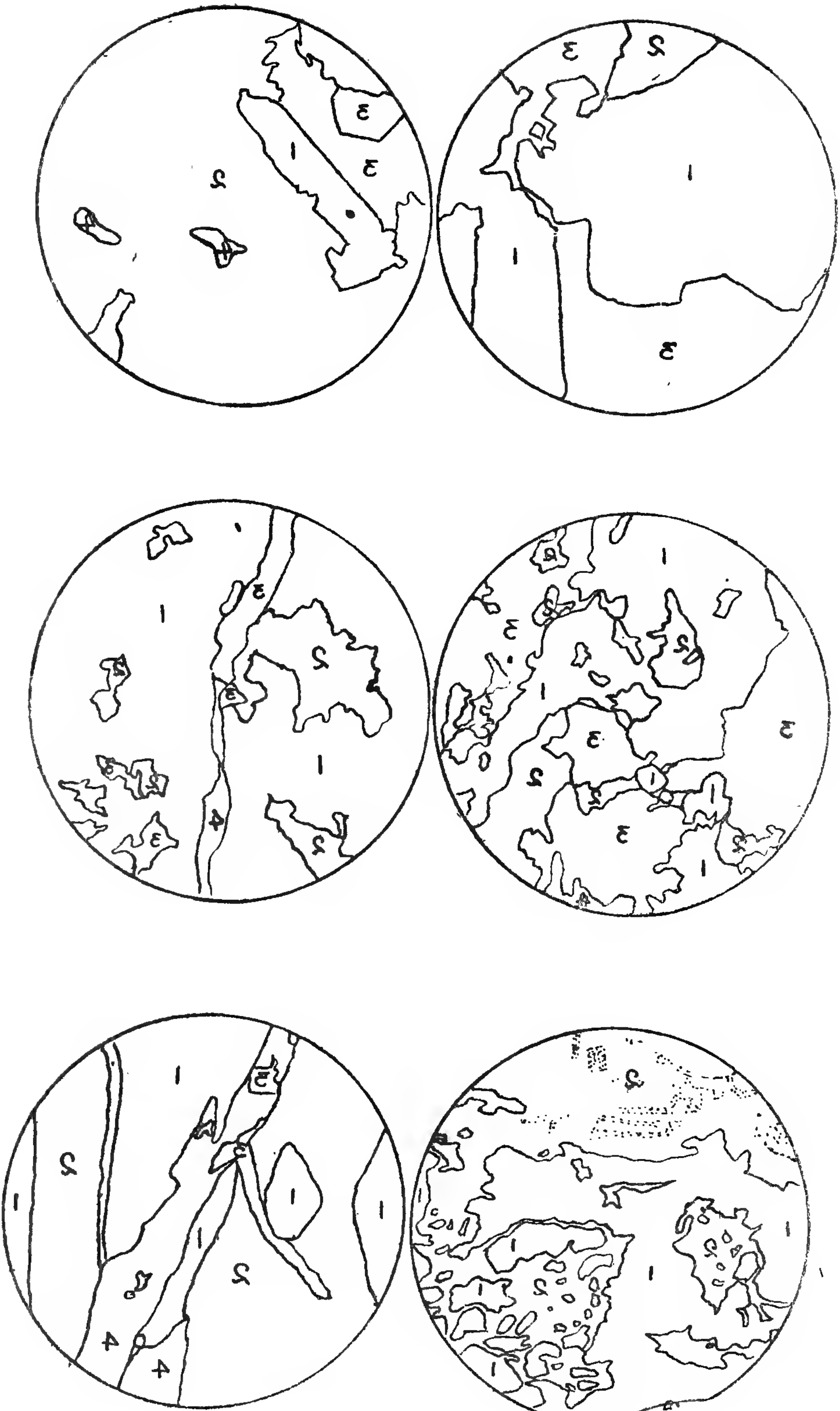


Fig. 1. × 14.

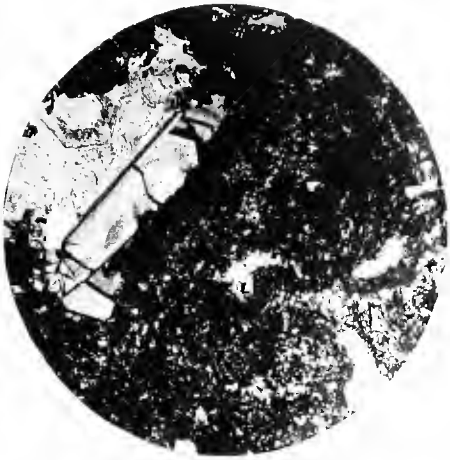


Fig. 2 × 14.

Fig. 3. × 14.

Fig. 4 × 14.

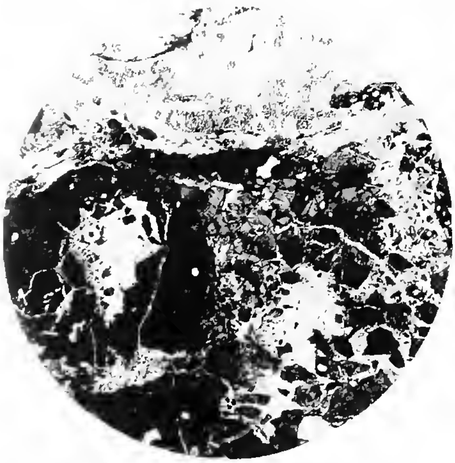


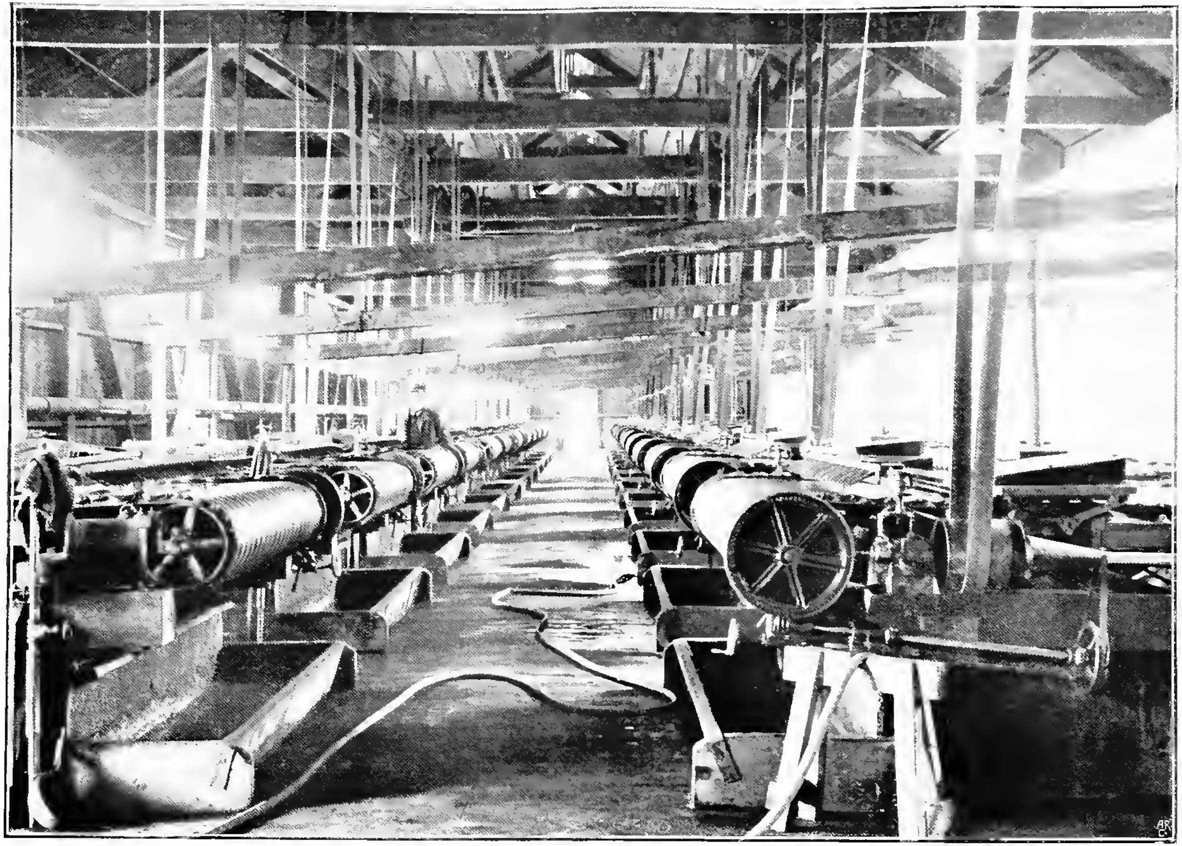
Fig 5. × 10.

Fig. 6 × 9.

STANNIFEROUS VEINS.

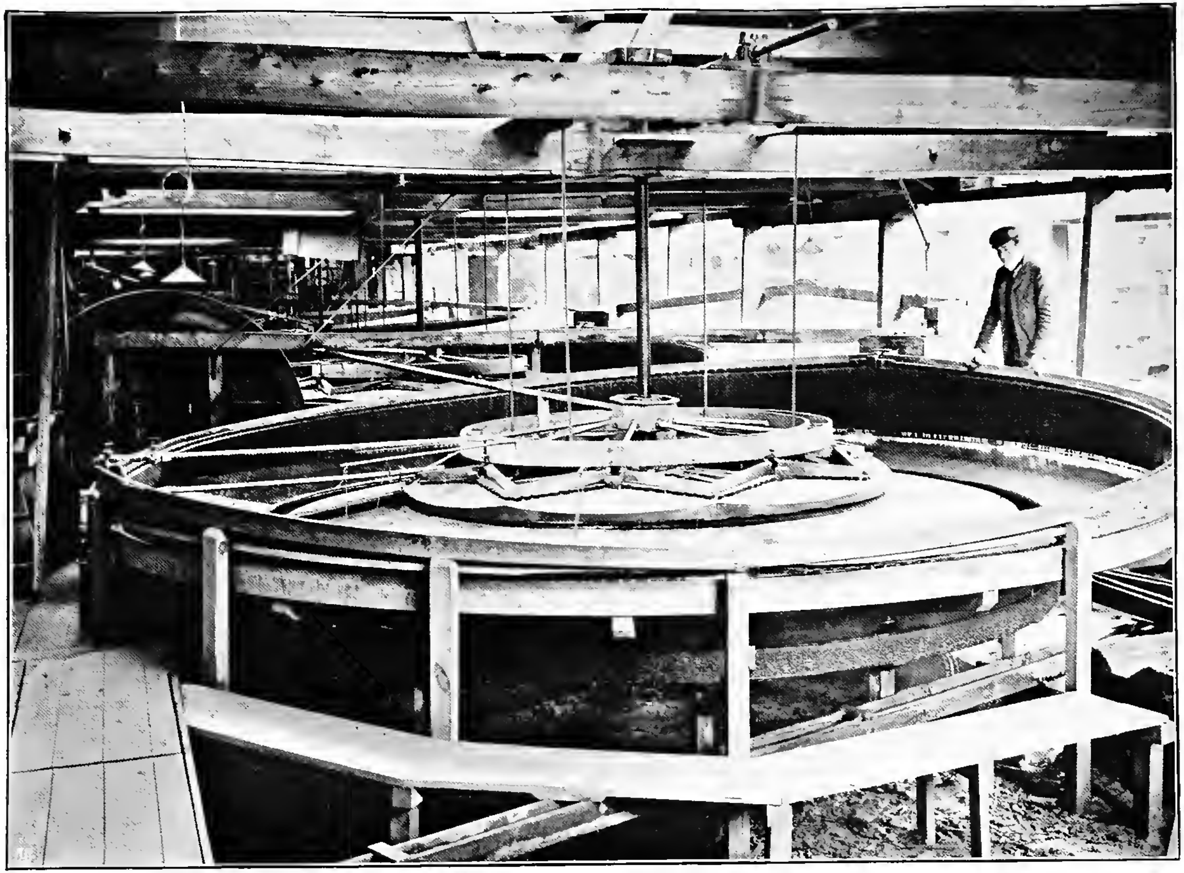
Cornish Stamps, South Crofty Dressing Floors.

PLATE XIV.

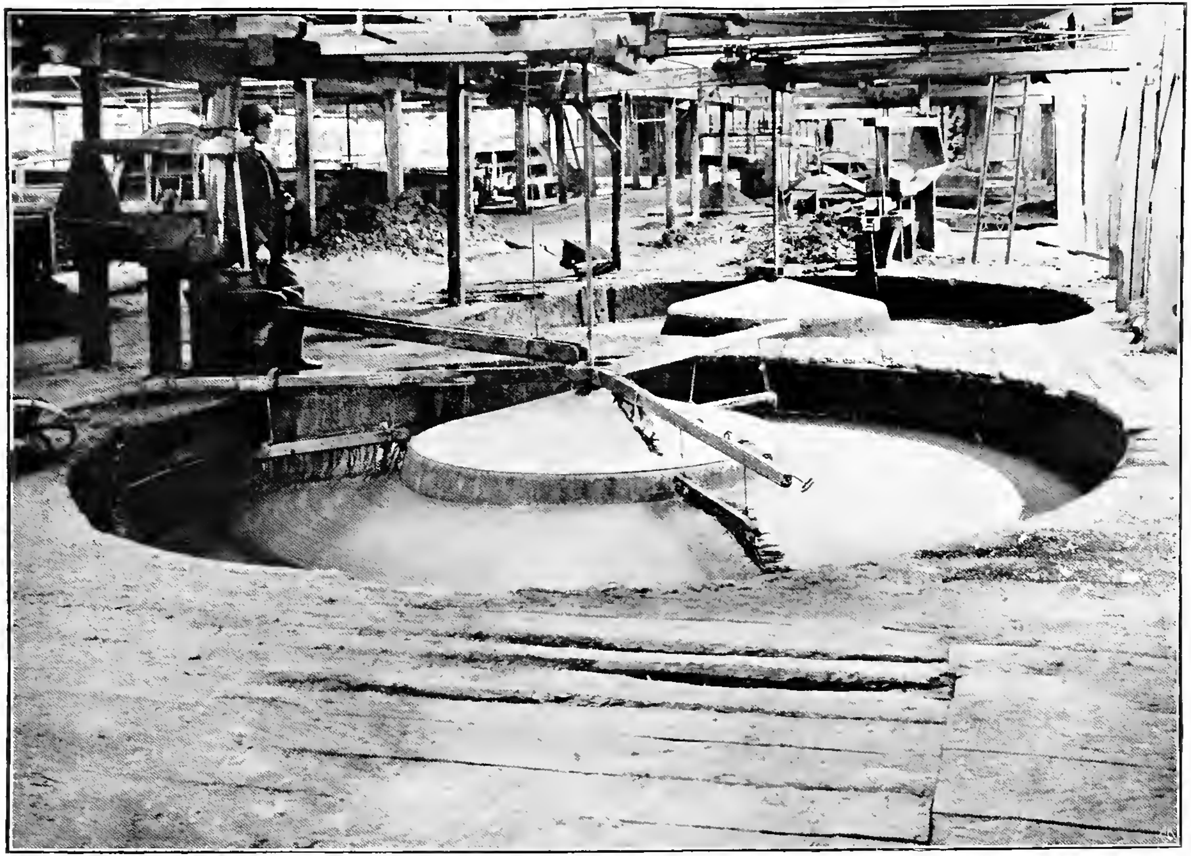


FRUE VANNERS, DOLCOATH DRESSING FLOORS

WILFLEY TABLES, DOLCOATH DRESSING FLOORS.

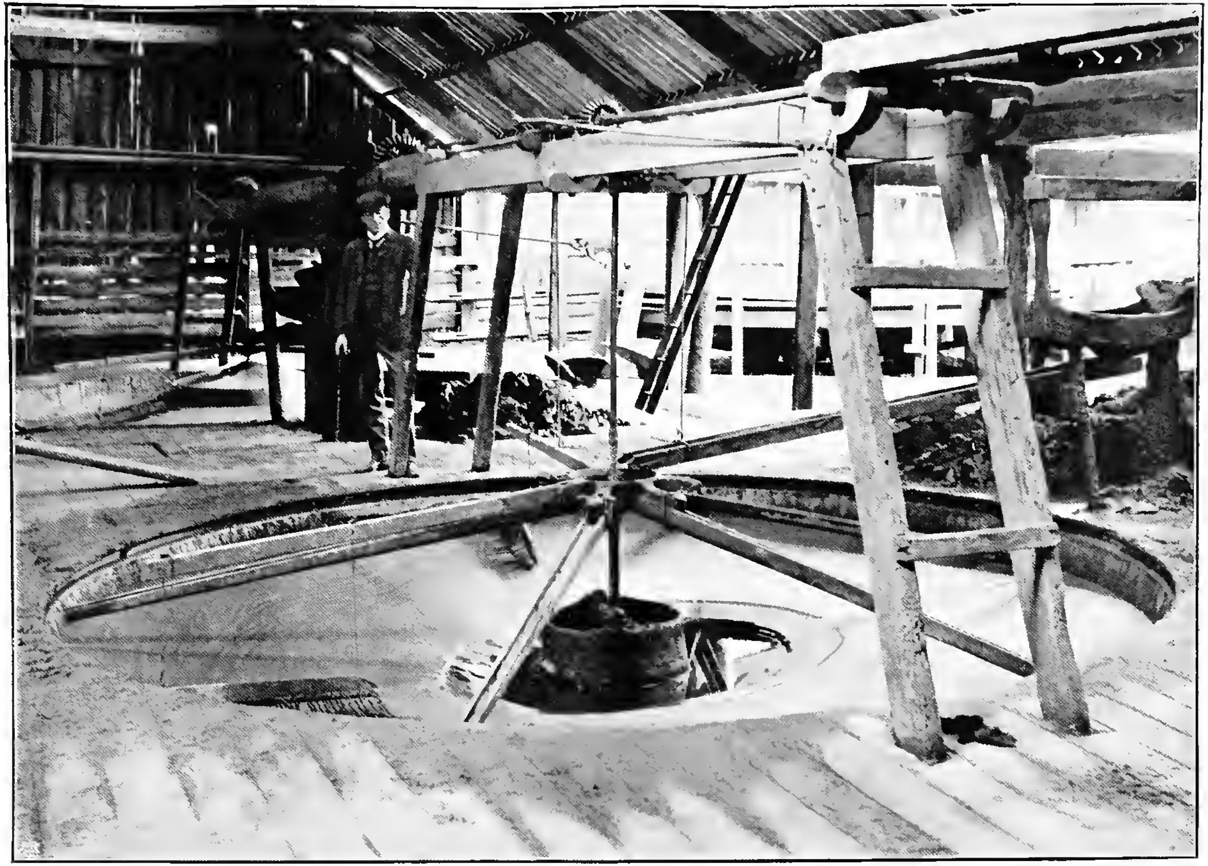


ACME TABLE, DOLCOATH DRESSING FLOORS.

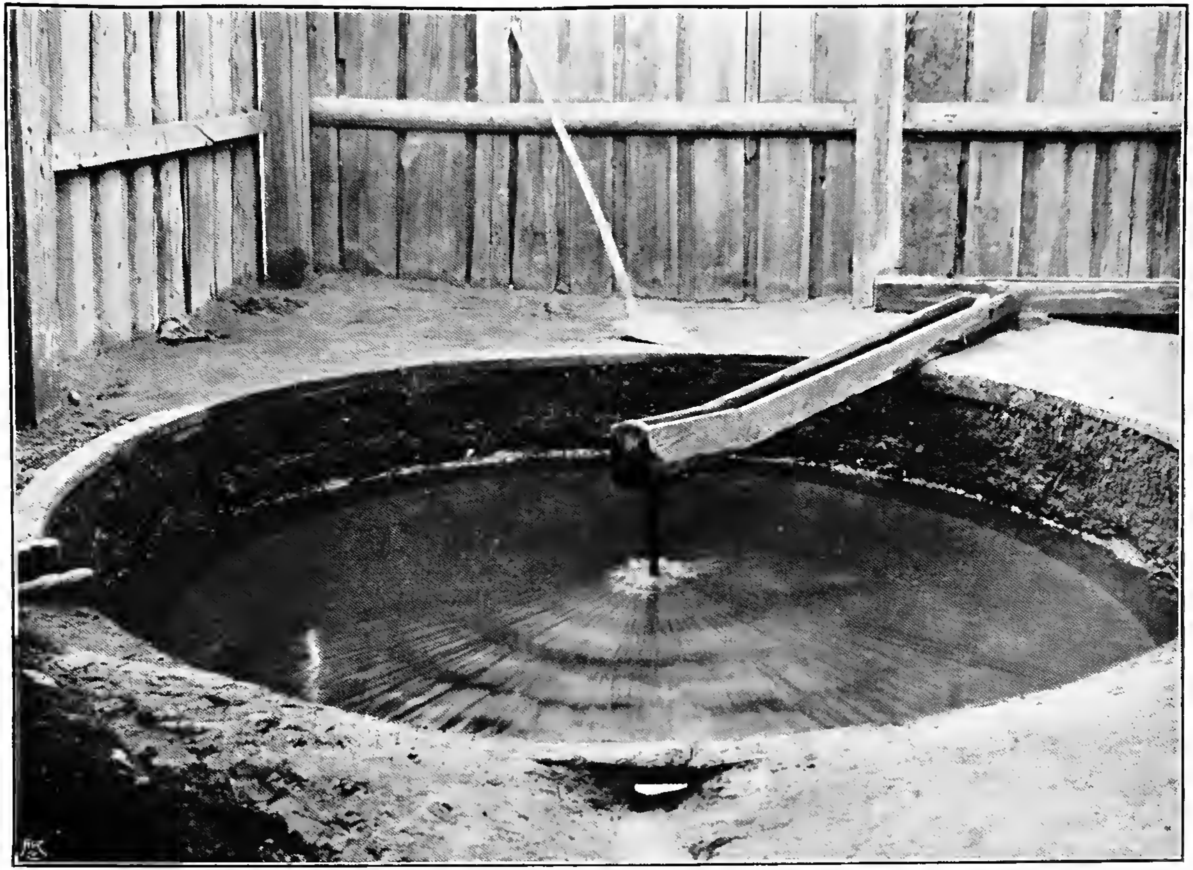


CONVEX BUDDLE, DOLCOATH DRESSING FLOORS.

Plate XVIII.

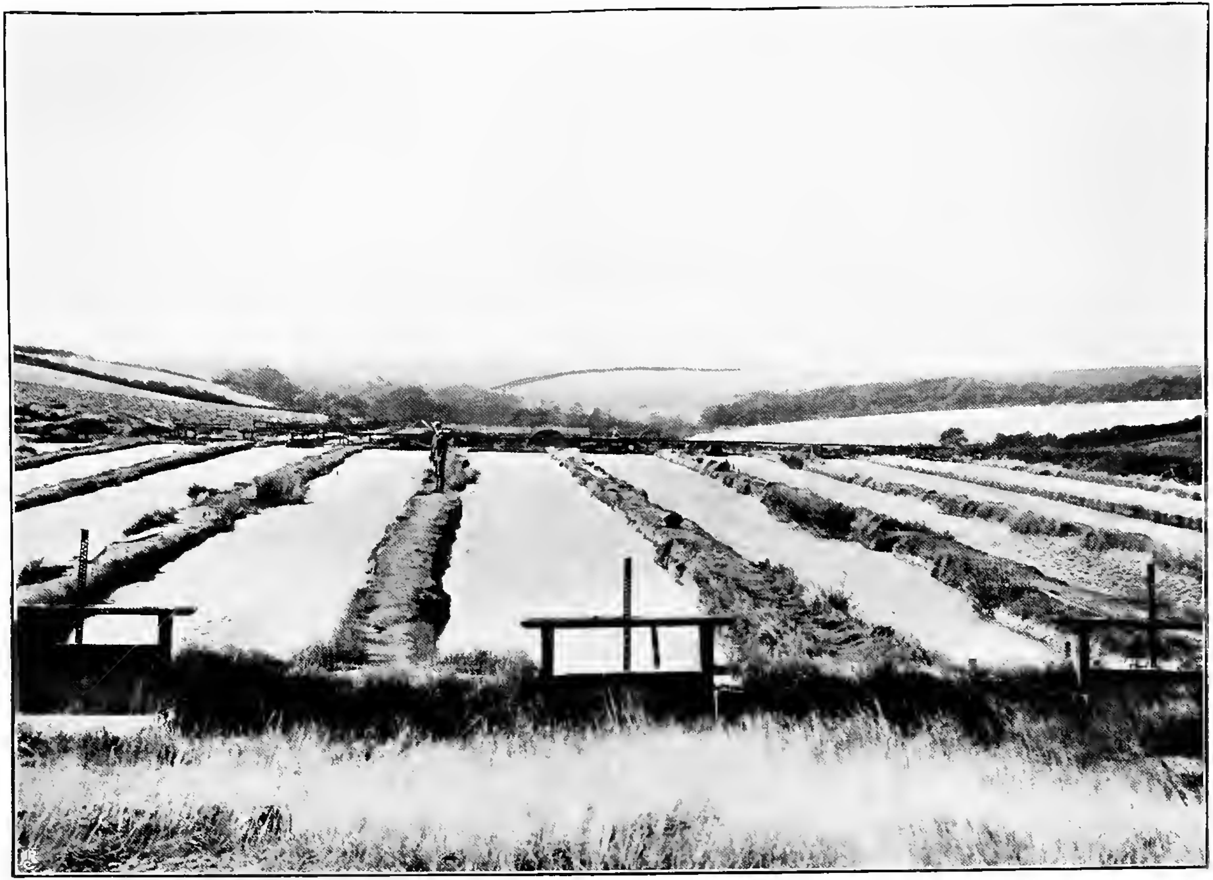


Concave Buddle. South Crofty Dressing Floors.

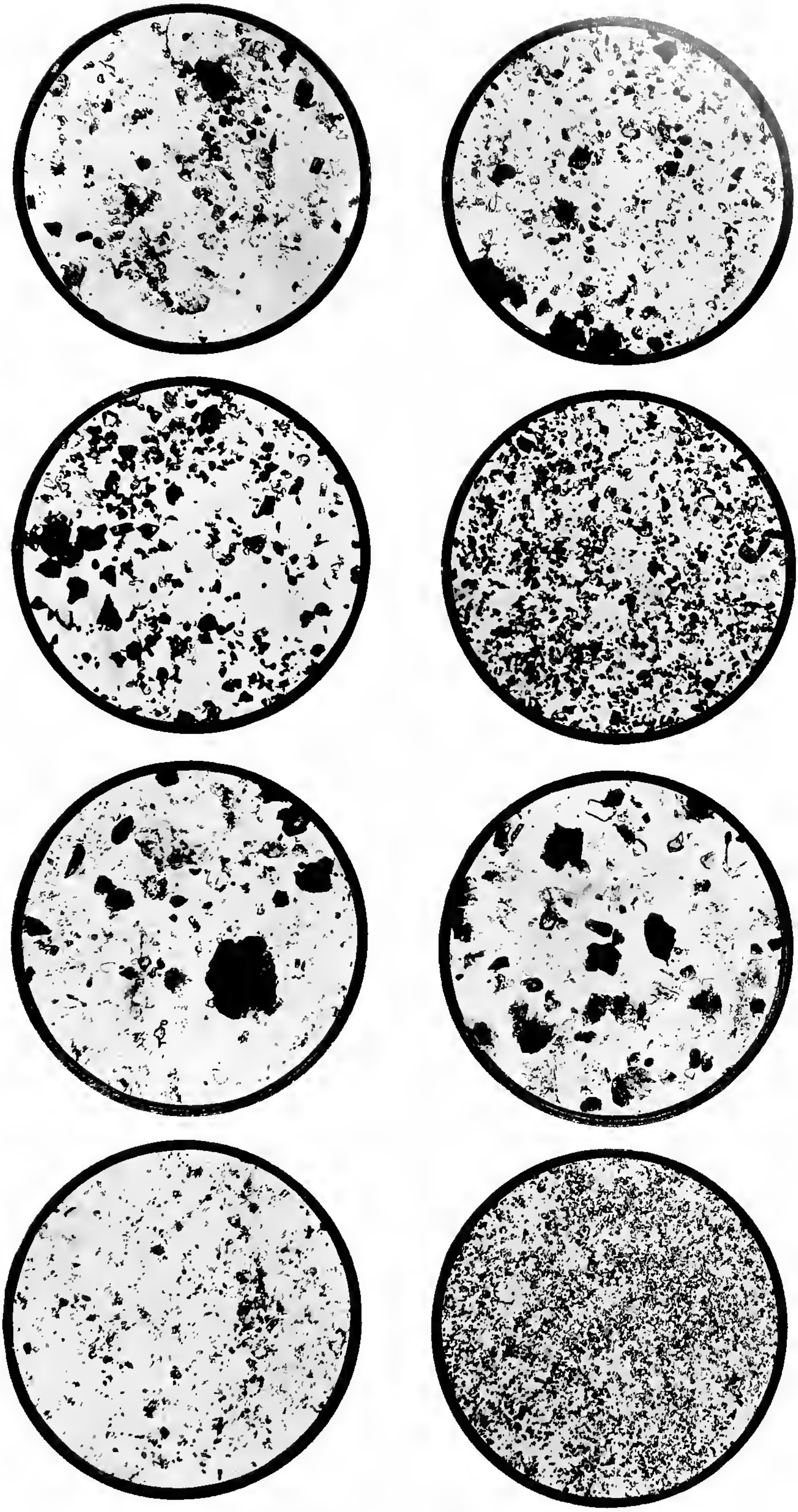


DUMB PIT, SOUTH CROFTY DRESSING FLOORS.

KIEVES, DOLCOATH DRESSING FLOORS.



SLIME PITS, KIEVE MILL, RESKUDINNICK.



1 2.

3. 4.

5. 6.

7. 8.

PRODUCTS FROM ORE DRESSING.

× 20.

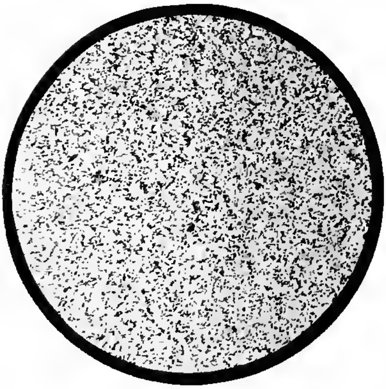
(see Chapter XVIII.).


1.

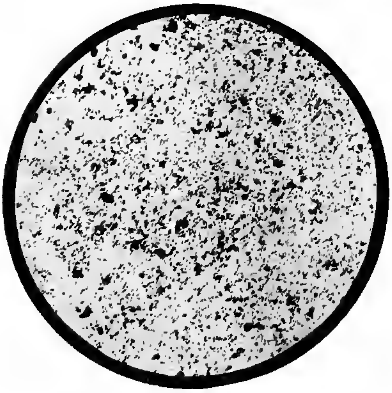

2.


3.


4.


5.


6.


7.


8.

Products from Ore Dressing.

× 20.

(see Chapter xviii.).

PLATE XXIV.

RAGGING FRAMES, KIEVE MILL, RESKUDINNICK.